United States Patent [19]

Powers

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[54] **PLURAL BEAM MASS SPECTROMETER AND METHOD OF CONDUCTING PLURAL BEAM STUDIES**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 112,716, Feb. 4, 1971, abandoned, which is a continuation-in-part of Ser. No. 638,133, May 12, 1966, Pat. No. 3,573,453.

[30] **Foreign Application Priority Data**

Aug. 20, 1970 Great Britain 41519/70

[52] **U.S. Cl.** **250/296**, 250/282, 250/285

[51] **Int. Cl.** **H01j 39/34**

[58] **Field of Search** . 250/41.9 SB, 41.9 SR, 41.9 G, 250/41.9 SA, 295, 296, 285, 396

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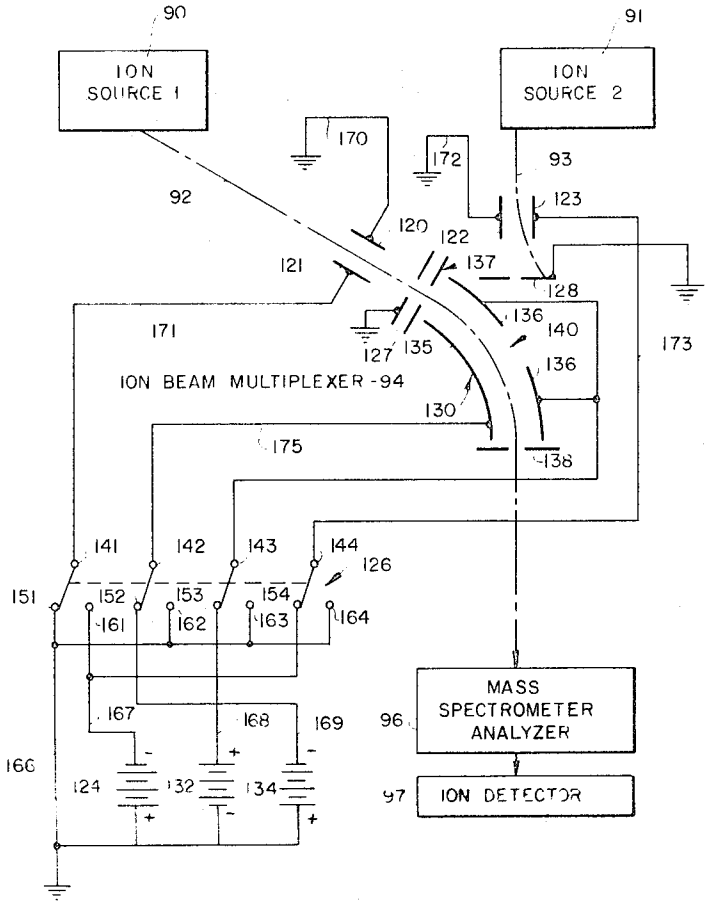
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[57] **ABSTRACT**

Plural ion beams emanating from one or more ion sources are conducted in multiplexed fashion through the magnetic analyzer of a mass spectrometer toward one or more collectors. In one embodiment, the beams traverse spaced paths and are received by separate collectors. In another embodiment, the beams are time division multiplexed along a common path and received by a single collector. The magnetic analyzer may be scanned during operation to simultaneously provide spectra for each of the beams and the mass spectral range of the beams compared.

24 Claims, 5 Drawing Figures



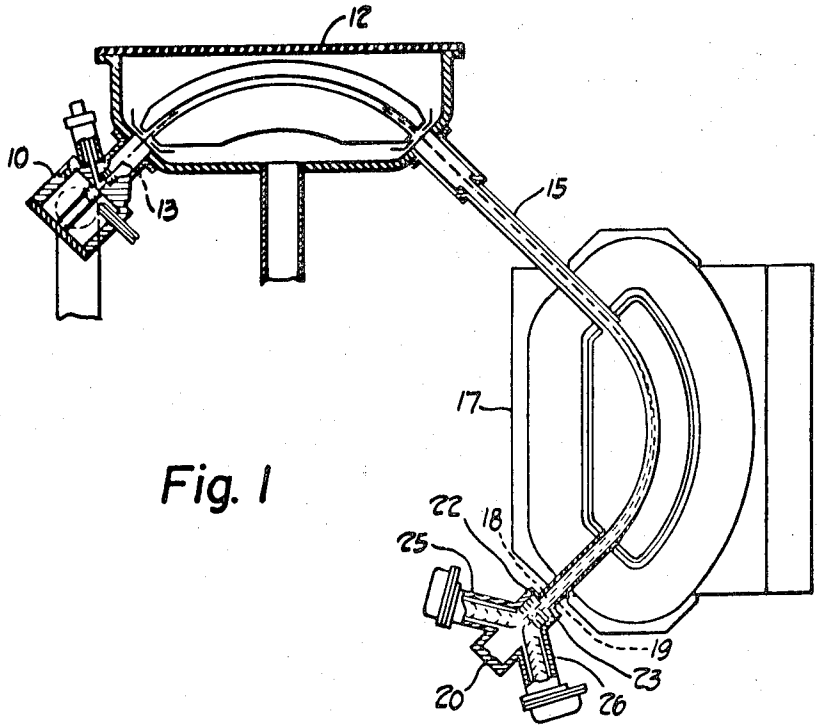


Fig. 1

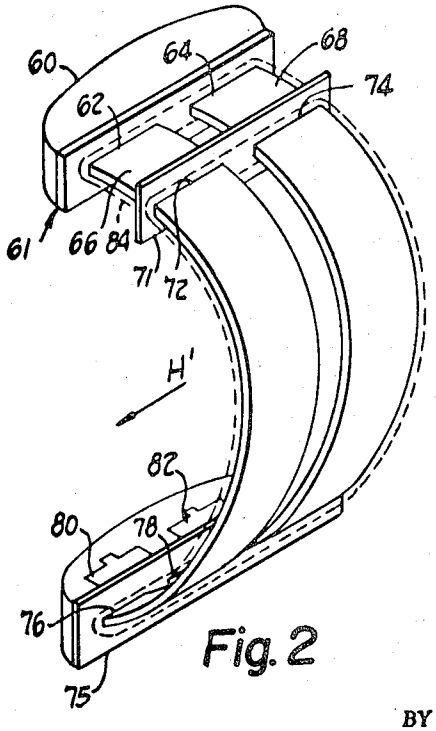


Fig. 2

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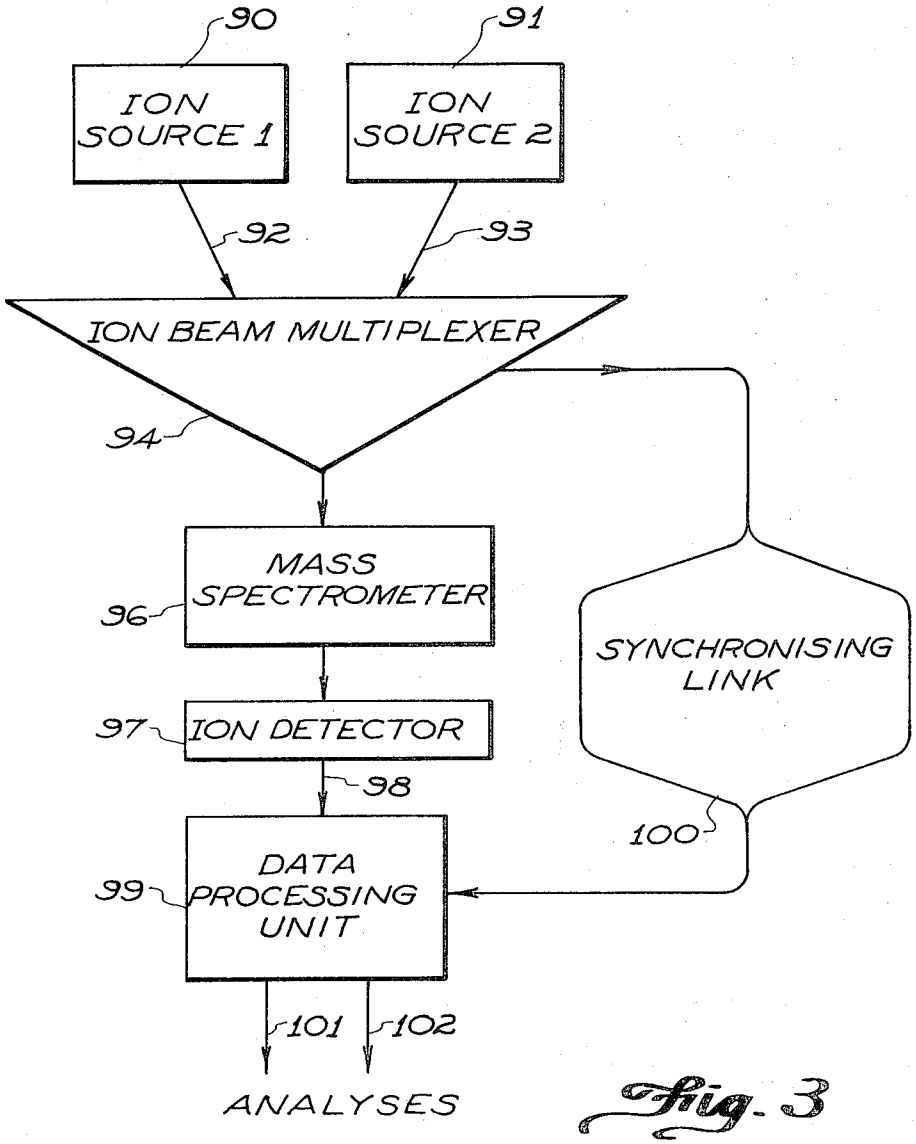


Fig. 3

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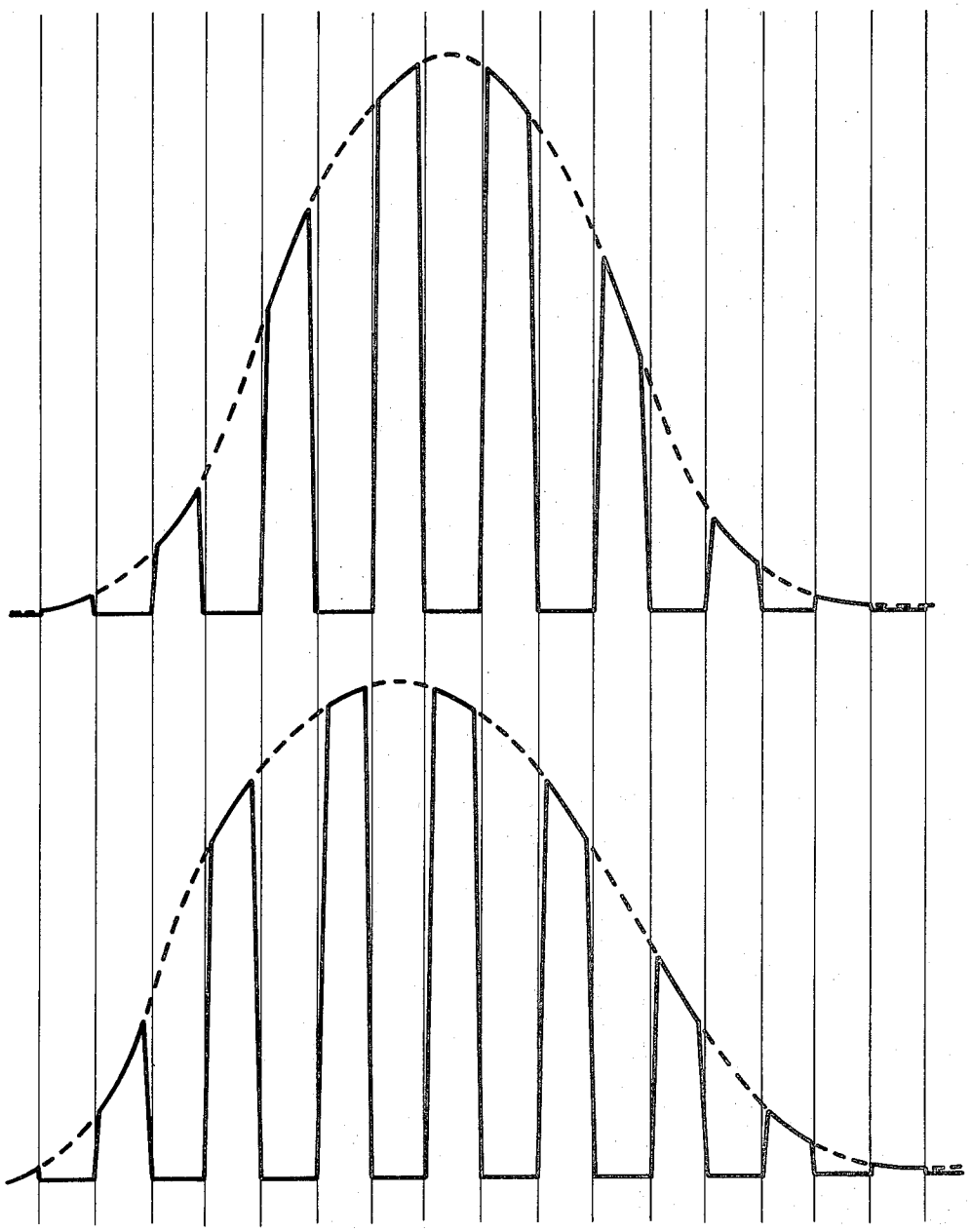


Fig. 4

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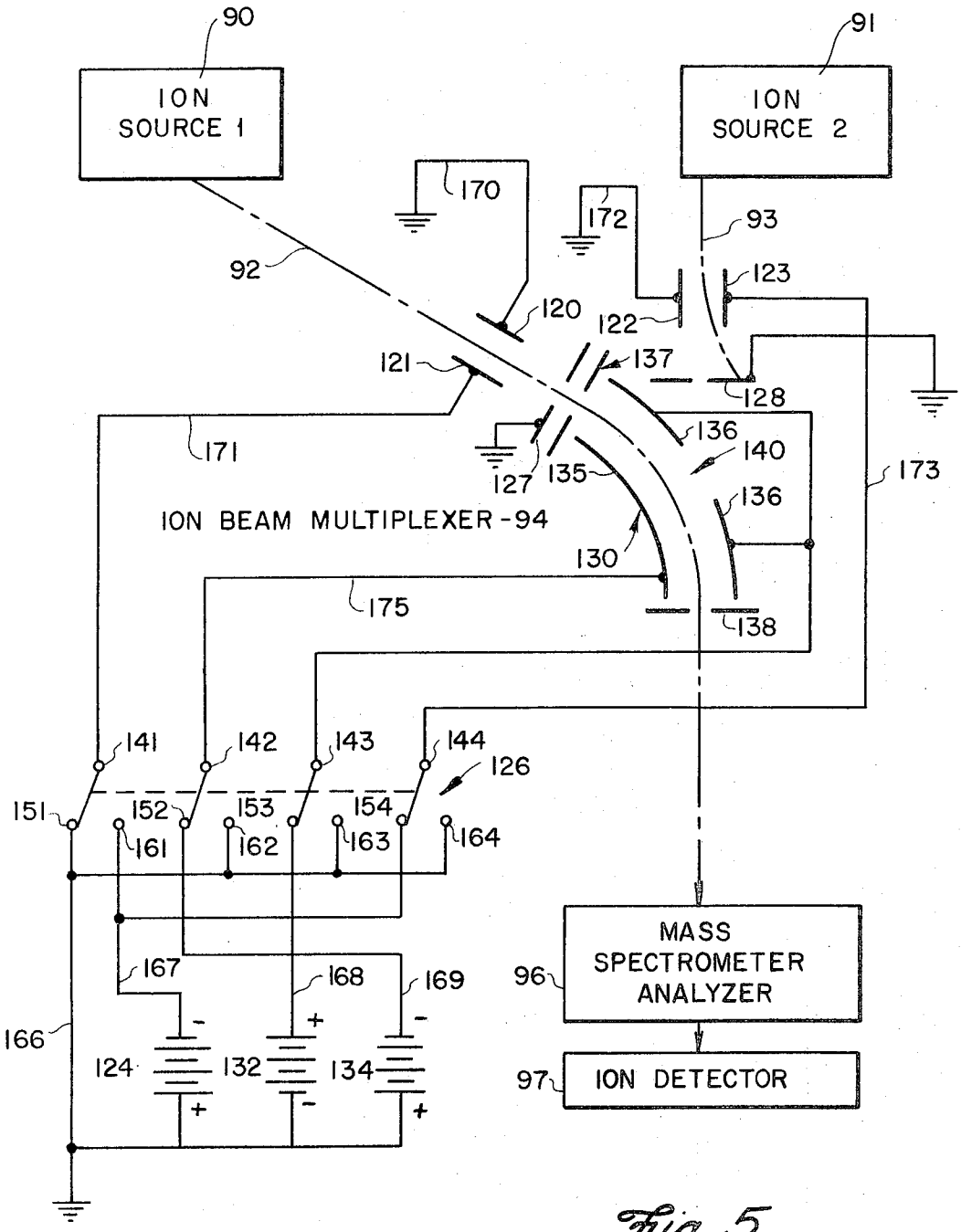

90
ION SOURCE 1
91
ION SOURCE 2
170
172
92
93
123
120
122
121
137
128
171
136
140
127
135
173
ION BEAM MULTIPLEXER-94
136
130
175
138
141
142
143
144
126
151
152
153
154
161
162
163
164
167
168
169
166
124
132
134
MASS SPECTROMETER ANALYZER
96
ION DETECTOR
97

Fig. 5

PLURAL BEAM MASS SPECTROMETER AND METHOD OF CONDUCTING PLURAL BEAM STUDIES

CROSS REFERENCE TO RELATED PATENTS AND APPLICATIONS

The present application is a continuation-in-part of U.S. Pat. application Ser. No. 112,716 filed Feb. 4, 1971, now abandoned, which was, in turn, a continuation-in-part of U.S. Pat. application Ser. No. 638,133 filed May 12, 1966, and issued Apr. 6, 1971 as U.S. Pat. No. 3,573,453, referred to subsequently as the Plural Beam Patent.

IMPROVEMENT RELATING TO MASS SPECTROMETERS, U.S. Pat. No. 3,588,495, issued June 28, 1971 to John Stephen Halliday et al., referred to subsequently as the Sequential Resolution Patent.

BEAM CORRECTING DEVICE FOR MASS SPECTROMETERS AND METHOD OF OPERATION, U.S. Pat. Ser. No 039,240 filed May 15, 1970 by Sydney Evans et al., now U.S. Pat. No. 3,657,531 issued Apr. 18, 1972, referred to subsequently as the Hexapole Patent.

ION LENS SYSTEM FOR MASS SPECTROMETERS AND METHOD OF OPERATION, U.S. Pat. application Ser. No. 87,020 filed Nov. 4, 1970 by John S. Halliday et al., referred to subsequently as the Zoom Lens Patent.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to mass spectrometers and more particularly to a mass spectrometer for conducting high and low resolution studies of a substance or substances.

2. Prior Art

In an analysis of a given compound with a mass spectrometer, ions of a material to be studied are generated in a source and accelerated as an ion beam toward a collector. In a so-called single focusing mass spectrometer, the ions pass through a magnetic analyzer. In a so-called double focusing instrument, the ions pass through an electrostatic analyzer before passing through the magnetic analyzer and then to the collector.

During a given analytical study, the mass spectrometer may be scanned such that ions of different mass-charge ratios are focused on the collector at different times during the scan. One method of scanning is to vary the accelerating potential of the ion source. Another method of scanning is to vary the magnetic field of the magnetic analyzer so that the amount of deflection of the ions passing through the analyzer is varied. By either of these methods, ions of varying constructions and mass-charge ratios are focused on the collector at different times during the scan.

There are certain applications in mass spectrometry, such as the examination of chemical structures, in which it is necessary to measure the mass of each fragment peak in the mass spectrum to a high degree of accuracy. This may require using high resolution conditions so that the various chemical possibilities for each fragment can be determined. However, several chemical possibilities exist, and it is frequently necessary to also use an overall spectrum at low resolving power to observe broad peaks due to metastable transitions. Examination of these broad peaks can be helpful in confirming the fragmentation processes, but cannot, however, be easily detected and measured during a high resolution scan.

For example, with automatic operation of a mass spectrometer, the mass spectrum may be tape recorded during one or more scans at high resolving power, but the record will not contain full information relating to metastable changes occurring during the study. That is, the study will not include a low resolution study as well. Thus, a further study was required for low resolution analysis. Similarly with manual operation, two separate processes of analysis were required at separate times, one at low and one at high resolving power, to obtain all the necessary information.

Another problem which has existed with the prior art is that the partial pressures of a reference compound and certain samples are such that they cannot be analyzed when mixed together in a single ionization chamber. This is ture because the reference compound has such a high partial pressure that ionization of a sufficient quantity of sample molecules for reliable results does not occur.

SUMMARY OF THE INVENTION

The present invention relates to a method and apparatus for analyzing substances with a mass spectrometer by obtaining, in a given scan, two or more resolution spectra of a substance or substances to be analyzed.

In accordance with the present invention, plural ion beams emanating from one or a plurality of sources are conducted through a common magnetic analyzer in multiplexed fashion along a common beam path or along spaced beam paths to a common detector or to separate detectors.

In one embodiment of the invention, two ion beams emanating from either a single source or separate sources are passed through a common ion tube along spaced paths through a common analyzer. Two collector slits and two collectors are used to record spectra which will be offset in time. The recorded information may be fed to a computer and compared by the computer to produce an analysis of the material of the sample. This arrangement has the advantage, as compared with a mass spectrometer which has plural detectors concurrently emitting signals, of reducing, at any given time, the quantity of information which must be fed to and analyzed by a computer. By way of explanation, where two collectors are in continuous operation generating a continuous output from two ion beam analyses, two continuous signals are fed to the computer for study and comparison. The present arrangement effectively increases the capacity of a computer in that at any given time a single input signal is provided from either a single collector or separate collectors. Signals are sequentially supplied from each of the separate ion beams so that the accumulated data results from all beams.

In the preferred embodiment, two ion beams emanating from either separate ionization regions or sources are time division multiplexed along a common path through a single analyzer. A single collector is coordinated with the multiplexing of the ion beams to provide separate data outputs of the spectra of the beams. This preferred embodiment provides a single beam mass spectrometer with the analytical capabilities of a multiple beam mass spectrometer.

A time division multiplexing apparatus is provided for time division multiplexing a plurality of ion beams to form a multiplexed beam which is then conducted through the analyzer of a mass spectrometer for analysis. The multiplexing apparatus, in one embodiment comprises pairs of plates at controlled voltages for selectively passing one of the plurality of beams at a time and for directing the multiplexed ion beam into the magnetic analyzer of the mass spectrometer. As an alternative to, or as an augmentation to the charged plates, the ion beam deflecting arrangement of the referenced Hexapole Patent may be used. The ion sources are preferably aligned such that the ion beams emanating therefrom intersect. The ion beam multiplexing apparatus is positioned to selectively pass one or the other of the beams into the magnetic analyzer of the mass spectrometer.

Where it is desired to provide different relative sensitivities of the ion collections from each of the separate multiplexed beams, the multiplexer apparatus can be used so as to multiplex each beam for a different selected time interval than another beam.

The apparatus may also be provided with an ion lens system of the type described in the Zoom Lens Patent for varying the focusing of the single multiplexed ion beam so as to effectively vary the resolution of collection of the single ion beam.

Accordingly, it is the object of the present invention to provide a novel and improved mass spectrometer and process of operating a mass spectrometer for improved analysis of substances.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims taken in conjunction with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partially schematic plan view of a double focusing mass spectrometer having a single ion source and a collector structure for collecting two separate ion beams;

FIG. 2 is a partially schematic perspective view showing a single ion source with a slit structure for producing two ion beams received by separate collectors;

FIG. 3 is a schematic diagram showing two ion sources producing two separate ion beams which are time division multiplexed and fed along a common beam path to a common collector;

FIG. 4 is a graphical representation of the results obtainable with the apparatus of FIG. 3; and,

FIG. 5 is still another schematic illustration of an apparatus arranged in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

One form of the invention, shown in FIG. 1, is incorporated in a double focusing mass spectrometer including an ion source 10 for producing ions of a substance to be analyzed. The ions are accelerated and are directed toward an electrostatic analyzer 12 as an ion beam 13. The ion beam 13 is delineated by slit structure in the ion source and other slit structure along its path of travel. After entering and emerging from the electrostatic analyzer 12, the ion beam 13 enters an ion tube 15 which passes between the coils of a magnetic analyzer 17, only one coil of which is shown. As the ions progress through the ion tube 15 they are mass separated along two beam trajectories 18, 19 and are deflected by a magnetic field directed substantially transverse to the path of travel of the ion beams into detectors 25, 26. In FIG. 1, the magnetic field is directed normal to the plane of the drawing.

The beams 18, 19 are collected in a collector unit designated generally by the numeral 20. The collector unit 20 includes slit structure defining a plurality of slits 22, 23 for delineating the ion beams 18, 19. The ion beams 18, 19, after passing through the slits 22, 23 impinge on collectors comprising electron multipliers 25, 26 which provide indications of the respective compositions of the ion beams 18, 19.

Another form of the invention is shown schematically in a single focusing mass spectrometer in FIG. 2 and includes a single ion source 60. A member 61 having source slits 62, 64 receives ions from the ion source 60. The ions produced in the ion source 60 are emitted through the source slits 62 64 to emerge as separately delineated ion beams 66, 68. A member 71 has collimating slits 72, 74 lying in a common plane to delineate and to prevent interaction of the ion beams 66, 68 respectively. The ion beams 66, 68 are deflected by a magnetic field H' directed transversely to their path of travel and ultimately reach a member 75 having collector slits 76, 78. The ion beams 66, 68 pass through collector slits 76, 78 and are collected on collectors 80, 82. A single ion tube 84, indicated by the dotted lines, surrounds both of the ion beams 66, 68. The magnetic field H' will deflect the beams as shown diagrammatically, and if varied, will focus ions of respective different masses successively at fixed positions toward the collector slits.

It should be realized that with this arrangement, a low resolution study of ions in a particular mass spectral range may be conducted simultaneously with a high resolution study of similar ions within a segment of the mass spectral range studied at low resolution. This differs from the operation of the apparatus shown in FIG. 1 with which the respective high and low resolution studies of ions of similar composition will be spaced somewhat in time.

Although the magnetic analyzer section described in conjunction with FIG. 2 is assumed to be for a single focusing spectrometer which uses magnetic deflection only, the method of analysis accomplished with such structure is also of importance with double focusing spectrometers which use both electrostatic and magnetic deflection systems.

In carrying out a method of analysis with the apparatus shown in described, the analysis of low resolution spectra and the establishment of the positions of broad metastable peaks, using the reference peaks in the high resolution spectrum are improved. This operation can be performed by a computer accompanying the mass spectrometer and the high resolution and low resolution results can be plotted as an output. As described previously with time division multiplexing beams from the plural sources sequentially reach their respective detectors so that the capacity of a computer is effectively increased.

In the description, means for simultaneously analyzing two separate beams of similar mass composition have been described. However, it is recognized that the present invention may be modified to accommodate the analysis of more than two ion beams.

In accordance with another aspect of the present invention, a plurality of ion beams emanating from one or more sources may be time division multiplexed along a common path. The multiplexed beam may be directed through the magnetic analyzer of a spectrometer having only single-beam capability and received by a single collector. The electrical signal produced by the collector may then be de-multiplexed to provide separate beam analyses. The beam analyses so produced are substantially equivalent to those obtainable by analysis of the ion beams in individual mass spectrometers or in plural beam mass spectrometers.

Referring to FIG. 3, two ion sources 90, 91 are shown producing ion beams 92, 93. The beams 92, 93 are directed into an ion beam multiplexer 94. The multiplexer 94 may comprise any of a number of known arrangements for alternately sweeping the beams 92, 93 across a collimating slit, whereby a single beam path 95 is used by alternate segments of each of the beams 92, 93.

The multiplexed beam 95 is then directed through the magnetic analyzer 96 of a mass spectrometer toward a collector 97. The collector produces a representative electric signal indicated by the arrow 98. This signal may then be de-multiplexed with any of a variety of well known data processing devices shown representatively at 99. A syncronizing link 100 may coordinate the operation of the data processing unit 99 with the ion beam multiplexer 94, whereby separate spectra analyses 101, 102 are provided for each of the beams 92, 93.

Referring to FIG. 4, there is shown a graphical plot of the results obtainable by multiplexing and analyzing the two ion beams. For the purposes of illustration, it is assumed that the mass spectrometer used is of the scanning type, and has been scanned over a range of mass-charge ratios including a ratio at which ions are present in both ion beams, such that the output of the mass spectrometer contains a peak for each beam. It is further assumed that multiplexing has been at such a rate relative to the scanning rate that multiplexing has occurred several times during the scanning of the peaks.

The horizontal axis represents both time and mass-charge ratio, and the vertical axis represents the intensity of the output signal of the mass spectrometer. The vertical lines spaced across FIG. 4 represents the instants at which multiplexing between one beam and the other occurs, and sampling and digitizing of the output signal occurs approximately half-way between those intervals.

The output signals appropriate to each beam have been separated vertically to more clearly show the results which will be seen to be a series of pulses at varying amplitudes. The dashed lines represent the continuous profiles of the peaks and together with the pulse taps shown the output signal that would be obtained if the beams were not multiplexed.

While the specific embodiment of FIG. 4 has been described as analyzing two ion beams, the invention may be applied to the analysis of more than two ion beams by equipping the apparatus of FIG. 4 with more than two ion sources and suitably adjusting the functioning of the ion beam multiplexer 94 and the data processing unit 99.

As will be apparent in FIGS. 3 and 4, the beams 92 and 93 have been sampled for alternate intervals with the intervals being of equal time. Such an arrangement provides for an equally sensitive analysis of each of the beams. By altering the gating time widths of the respective beams, the ratio of sensitivities of the beam analyses may be correspondingly altered.

Mass marking can easily be performed in conjunction with the methods and apparatus of the present invention by arranging that one or more of the substances from which the ion beams are formed is a reference substance or substances capable of producing ions of known mass-to-charge ratios. Two examples of suitable reference substances are heptacosafluorotributylamine and perfluorokerosene.

Referring to FIG. 5, the ion beam multiplexer 94 which is interposed between the sources 90, 91 and the mass spectrometer 96 is shown. The ion source 91 is arranged such that the ion beam 93 emitted therefrom will when not subjected to transverse electrostatic fields, traverse a beam path which is aligned with the entrance of the mass spectrometer analyzer 96. The ion source 90 is arranged such that the ion beam 92 emanating therefrom will, when not subjected to transverse electrostatic fields, intersect the path of the beam 93 but will not enter the mass spectrometer 96. The multiplexer 94 is positioned near the intersection of the beam paths and serves to time division multiplex the beams 92, 93 and direct the resulting multiplexed beam into the mass spectrometer analyzer 96.

The multiplexer 94 basically comprises two pairs of control plates 120, 121 and 122, 123, two pairs of slit structures 127, 128, and an arrangement of curved electrode plates generally indicated by the numeral 130. As will be explained, a switching system generally indicated by the numeral 126 is provided which selectively grounds or supplies a potential difference across the pairs of plates 120, 121 and 122, 123 to selectively pass the beams 92, 93 through the slit structures 127, 128 or to divert the beams onto the slit structures 127, 128. When the beam 92 is passed through the slit structure 127, the curved electrode plates 130 are provided with such a voltage potential as will divert the beam 92 into the mass spectrometer analyzer 96. When the beam 93 is passed through the slit structure 128, the curved electrode plates 130 are grounded so as to permit the direct passage of the beam 93 into the mass spectrometer analyzer 96.

The switching structure 126 is schematically illustrated as comprising a four pole double throw switch. This switching system can, and preferably does, comprise a solid state device for respectively connecting terminals 141, 142, 143, 144 to terminals 151, 152, 153, 154 or to terminals 161, 162, 163, 164. The terminals 151, 162, 163, 164 are connected by means of a conductor 166 to ground. The terminals 161, 154 are connected by means of a conductor 167 to the negative terminal of a voltage source 124. The terminal 153 is connected by a conductor 168 to the positive terminal of a voltage source 132. The terminal 152 is connected by a conductor 169 to the negative terminal of a voltage source 134.

The control plate pairs 120, 121 and 122, 123 each have one plate, namely the plates 120, 122, permanently connected to ground by means of conductors 170, 172. The other plates 121, 123 are connected by means of conductors 171, 173 to the terminals 141, 144. When the switching structure 126 is positioned to connect the terminals 141, 151 and 144, 154, the plate

121 is connected to ground and the plate 123 is connected to the negative potential 124. This arrangement will permit the beam 92 to pass readily between the plates 120, 121 and through the opening defined by the grounded slit structure 127, while it will cause the beam 93 to be diverted onto the grounded slit structure 128 as shown in FIG. 5. When the switching structure 126 is positioned to connect the terminals 141, 161 and 144, 164, the plate 121 is connected to the negative potential 124, and the plate 123 is connected to ground. This arrangement will permit the beam 93 to pass readily between the plates 122, 123 and through the opening defined by the grounded slit structure 128, while it will cause the beam 92 to be diverted on to the grounded slit structure 127.

The beam deflector 130 comprises a pair of curved deflector plates 135, 136. The plate 136 is segmented so as to provide a gap 140 through which the beam 93 can pass directly into the mass spectrometer analyzer 96. The deflector plate 135 is connected by a conductor 175 to the terminal 142. The deflector plate 135 is connected by a conductor 175 to the terminal 142. The deflector plate 136 is connected by a conductor 176 to the terminal 143. When the switching structure 126 is positioned as shown in FIG. 5 such that the terminals 142, 152 and 143, 153 are connected, the plate 135 is connected to the negative potential 134 and the plate 136 is connected to the positive potential 168. This serves to deflect the beam 92 into the mass spectrometer analyzer 96, as shown in FIG. 5. When the switching structure 126 is positioned such that the terminals 142, 162 and 144, 164 are connected, the plates 135, 136 are grounded so as to permit the undisturbed passage of the beam 93 through the gap 140 and directly into the mass spectrometer analyzer 96.

Fringe field correcting plates 137, 138 are preferably provided at the entrance and exit of the beam deflector structure 130. The beam correction structures 137, 138 can be of the type disclosed in the Hexapole Patent.

In operation, the switching structure 126 can be operated so as to spend equal or un-equal times in its two positions. Where the switch 126 spends equal times in its two positions, the relative sensitivities of the ion collections from the multiplexed beams will be equal so as to obtain the result shown in FIG. 4. If the switching structure 126 spends un-equal times in its two positions, more ions from one of the sources 90, 91 will reach the spectrometer 96 than from the other of the sources 90, 91, assuming both sources are producing ions at the same rates. This effectively controls the relative sensitivity of the ion collections. Thus the present invention provides an electronic control for adjusting sensitivity.

By adjusting the focusing of the single ion beam on the ion detector 97, the effective resolution may also be adjusted electronically. An ion lens system for varying the focus of an ion beam is described and claimed in the referenced Zoom Lens Patent. By combining the Zoom Lens with the present invention, electronic control systems are provided which enable both the sensitivity and the resolution of the analyses to be controlled as desired.

While the specific embodiment described in conjunction with FIG. 5 is intended to analyze only two ion beams, it will be apparent that a multiplexer can readily be provided which will time division multiplex more than two ion beams so as to provide analysis of more than two beams.

Although the foregoing description is necessarily of a detailed character, in order that the invention may be set forth, it is to be understood that the specific terminology is not intended to be restrictive or confining, and that various rearrangements of parts and modifications of detail may be resorted to without departing from the scope or spirit of the invention as herein claimed.

What is claimed is:

1. A method of operating a mass spectrometer comprising the steps of:
   a. time division multiplexing samples from a plurality of individual ion beams along a common path to form a multiplexed beam having alternate samples of each of said beams;
   b. passing the multiplexed beam through the magnetic analyzer of a mass spectrometer to analyze said multiplexed beam thereby effecting a substantially concurrent analysis of said ion beams;
   c. processing the output of the mass spectrometer to separate output portions relating to each of the individual ion beams to obtain separate information derived from each of the individual ion beams.

2. The method of operating a mass spectrometer of claim 1 including the additional step of scanning the mass spectrometer to provide separate mass spectra analysis date for each of the individual ion beams.

3. The method of operating a mass spectrometer of claim 2 including the further step of performing the multiplexing at a sufficiently rapid rate to effect sampling of individual peaks of the output signal a plurality of times.

4. The method of operating a mass spectrometer of claim 3 wherein the individual beams are sampled for equal intervals of time to provide analysis data of equal sensitivity for each of the individual ion beams.

5. The method of operating a mass spectrometer of claim 3 wherein the individual beams are sampled at an unequal time interval ratio to provide analysis data for the individual beams of a corresponding ratio of sensitivities.

6. A method of operating a mass spectrometer comprising the steps of:
   a. time division multiplexing samples from a plurality of individual ion beams along a common path to form a multiplexed beam having alternate samples of each of the individual ion beams;
   b. passing the multiplexed beam through the magnetic analyzer of a mass spectrometer to analyze the multiplexed beam;
   c. receiving the analyzed multiplexed beam in a collector which generates a representative electrical signal; and,
   d. processing the signal to separate portions relating to each of the ion beams to provide separate mass spectral analysis data for each of the individual ion beams.

7. The method of claim 6 wherein mass marking is performed by forming at least one of the individual ion beams from a reference substance capable of producing ions of known mass-to-charge ratios.

8. A method of operating a mass spectrometer comprising the steps of:

a. orienting a plurality of ion sources to produce separate ion beams directed along separate paths to a common intersection;
b. providing electrode means near said intersection of the beam paths to selectively divert each of said separate beams from reaching said intersection;
c. applying requisite voltage potentials to said electrode means to time division multiplex samples of said separate beams through said intersection so that only one of said separate beams is permitted at any one time to pass said electrode means and enter the region of said intersection, and rapidly changing said potentials to rapidly switch among the separate beams so passed thereby forming a multiplexed beam containing samples of all of said separate ion beams;
d. passing the multiplexed beam through the magnetic analyzer of a mass spectrometer to analyze said multiplexed beam
e. receiving the analyzed multiplexed beam and generating a signal representative thereof; and,
f. processing the signal by sampling and digitizing the resulting samples to provide mass spectral analysis data for the separate ion beams.

9. A mass spectral analysis method comprising the steps of time division multiplexing samples from a plurality of individual ion beams through the magnetic analyzer of a mass spectrometer to analyze the multiplexed samples collecting the analyzed output of the spectrometer, and processing this output to provide separate analysis data for each of said individual ion beams.

10. The mass spectral analysis method of claim **9** wherein the multiplexing time intervals for each of the individual ion beams is selectively adjusted to provide a desired sensitivity relationship between the analysis data of said individual ion beams.

11. The mass spectral analysis method of claim **10** wherein said time intervals are adjusted to provide analyses of equal sensitivity for each of said individual ion beams.

12. A mass spectrometer apparatus comprising:
a. ion beam deflecting means for time division multiplexing samples from a plurality of separate ion beams along a common path to form a multiplexed beam having alternate samples of each of said ion beams;
b. a magnetic analyzer disposed along said common path to analyze the multiplexed beam;
c. collector means adapted to receive the analyzed beam and provide a representative electric signal; and,
d. processing means adapted to de-multiplex said signal by performing the inverse of the multiplexing process to provide separate mass spectral analysis data for each of said separate beams.

13. The apparatus of claim **12** wherein said processing means comprises a digital computer adapted to sample and digitize said signal in coordination with the operation of said ion beam deflecting means.

14. The apparatus of claim **12** wherein said processing means comprises a data processing unit, and a synchronizing means coordinates the operation of said data processing unit with the operation of said ion beam deflecting means.

15. Mass spectral analysis apparatus comprising ion beam deflecting means for time division multiplexing samples from a plurality of separate ion beams through the variable field magnetic analyzer of a mass spectrometer at a multiplexing rate which is more rapid than the rate at which the magnetic field is varied to analyze the multiplexed samples.

16. The apparatus of claim **15** additionally including means connected to said ion beam deflecting means for de-multiplexing the output signal of a collector positioned to receive the analyzed beam to provide analysis data representative of each of said separate ion beams, de-multiplexing being synchronously correlated with the multiplexing.

17. The apparatus of claim **15** wherein said ion beam deflection means comprises:
a. gate means adapted to receive and selectively pass or block each of a plurality of separate ion beams;
b. control means for controlling the operation of said gate means to selectively pass only one of said separation ion beams at a time; and,
c. beam direction means for directing the resulting multiplexed beam into a mass spectrometer.

18. The apparatus of claim **17** wherein said gate means comprises separate electrode means positioned along the normal paths of travel of each of said separation ion beams for selectively diverting each of said separation beams from their normal paths of travel.

19. The apparatus of claim **18** wherein said control means comprises a switching system for connecting selected ones of said electrode means either to ground or to a selected potential such that said separation ion beams are either passed undisturbed along their normal paths of travel or are diverted from their normal paths of travel.

20. In mass spectral analysis apparatus including a mass spectrometer having an analyzer of the type which separates ions according to their mass to charge ratios and deflects ions so separated into an ion collector to produce an output representative of collected ions, the improvements comprising:
a. first and second ion sources arranged to simultaneously produce separate ion beams traveling along first and second intersecting paths to an intersection;
b. time division multiplexing means interposed between said sources and said intersection for selectively passing samples of said separate beams one at a time to said intersection; and,
c. beam deflection means positioned in the region of said intersection for directing said samples into a mass spectrometer analyzer.

21. The apparatus of claim **20** wherein said time division multiplexing means is positioned near said intersection and said second path is aligned with the entrance to said analyzer.

22. The apparatus of claim **21** additionally including control means coordinating the operation of said multiplexing means and said beam deflection means such that said beam deflection means is operative only during such times as said multiplexing means passes ions from said first source into the region of said intersection, whereby ions from said second source which are passed by said multiplexing means travel undisturbed through said beam deflection means and into said analyzer.

23. A method of operating a mass spectrometer having a plurality of ion sources, a magnetic analyzer, and

an ion detector responsive to ions passing through said analyzer to produce an ion representative output signal comprising the steps of:

a. simultaneously operating each of the ion sources to produce respective ion beams;

b. making a scanning variation of the magnetic field in the magnetic analyzer;

c. performing an ion beam switching operation on all the ion beams at a more rapid rate than the rate of variation of the magnetic field, to direct samples from each of the ion beams singly and in rapidly repeated succession into the magnetic analyzer whereby to time division multiplex samples from the ion beams through said analyzer; and,

d. processing the output of the mass spectrometer by passing the ion representative output signal through a data processing unit to provide mass spectral analysis data for the ion beams.

24. A method of operating a mass spectrometer having first and second ion sources, an ion beam deflector, a magnetic analyzer, and an ion collector, comprising the steps of:

a. simultaneously operating the first and second ion sources to produce respective first and second ion beams;

b. simultaneously directing the first and second ion beams into the ion beam deflector;

c. making a scanning variation of the magnetic field in the magnetic analyzer;

d. operating the ion beam deflector to pass samples from the first and second ion beams alternately into the magnetic analyzer, the alternation occurring at a rapid rate relative to the rate of variation of the magnetic field whereby to time division multiplex samples from the first and second ion beams into said analyzer;

e. collecting on said ion collector mass analyzed ions which have passed through said magnetic analyzer; and

f. processing the output signal from said ion collector by sampling and digitizing said signal and passing said digitized samples through a data processing unit to provide mass spectral analysis data representing respective mass spectral analyses of said first and second ion beams.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,831,026 Dated August 20, 1974

Inventor(s) Patrick Powers

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

[30] Foreign Application Priority Data

ADD:

May 17, 1966 Great Britain Provisional.....21827/66

August 26, 1971 Great Britain Complete.....41519/70

Column 2, line 19, "ture" should be - - true - -

Column 5, line 4, after "may" insert - - then - -

Signed and sealed this 11th day of February 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks

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