

Oct. 7, 1952

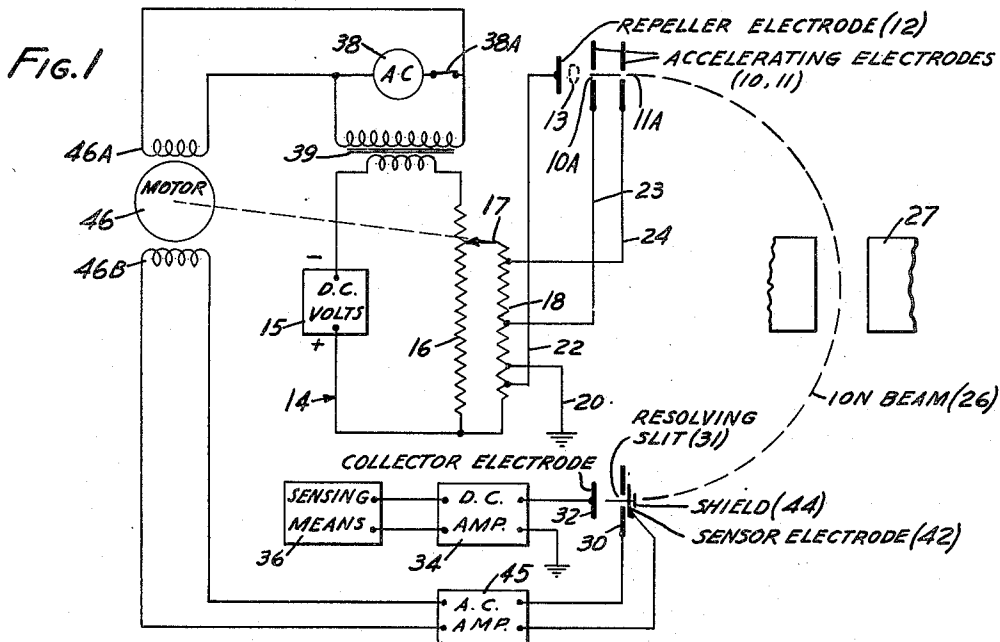
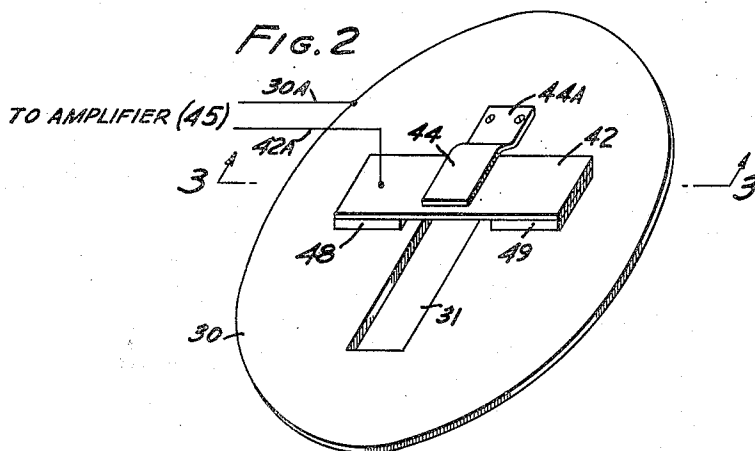
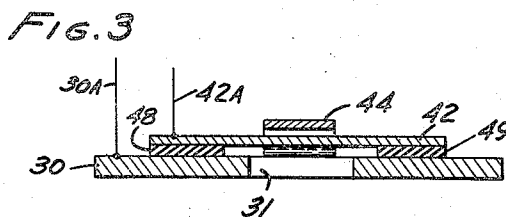
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2,613,324

MASS SPECTROMETRY

Filed Nov. 15, 1949

4 Sheets-Sheet 1



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FIG. 4

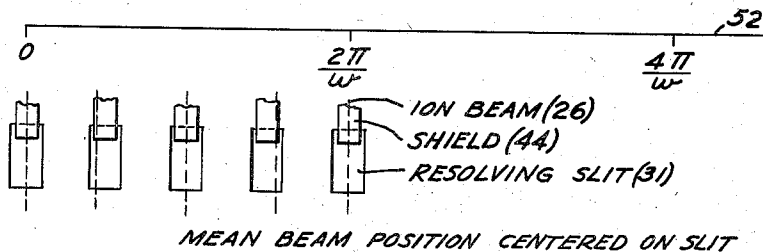


FIG. 4A

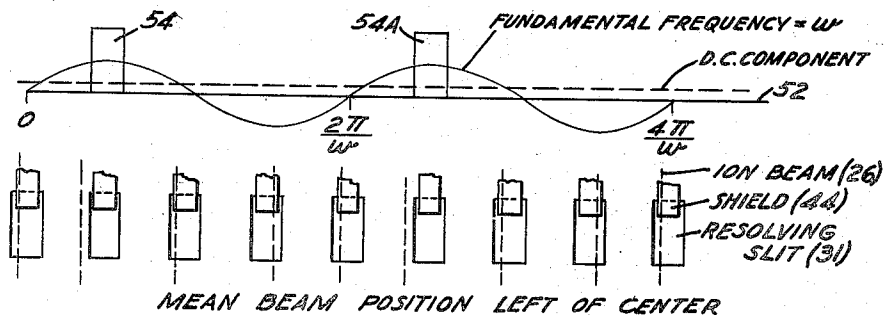
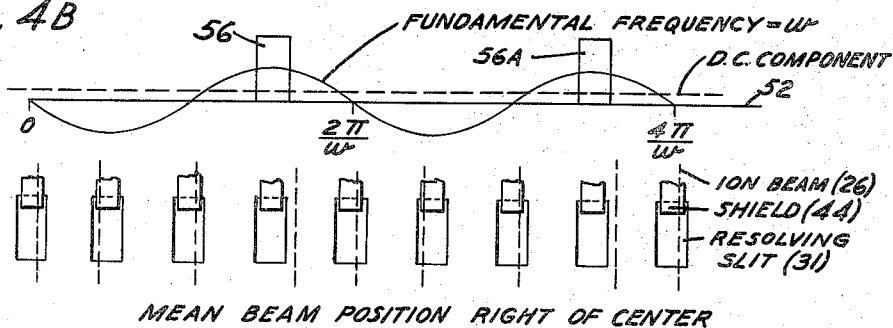


FIG. 4B



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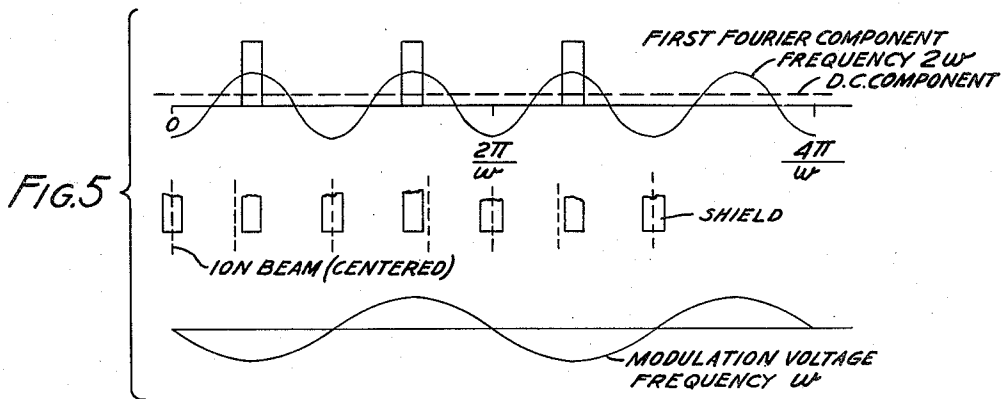
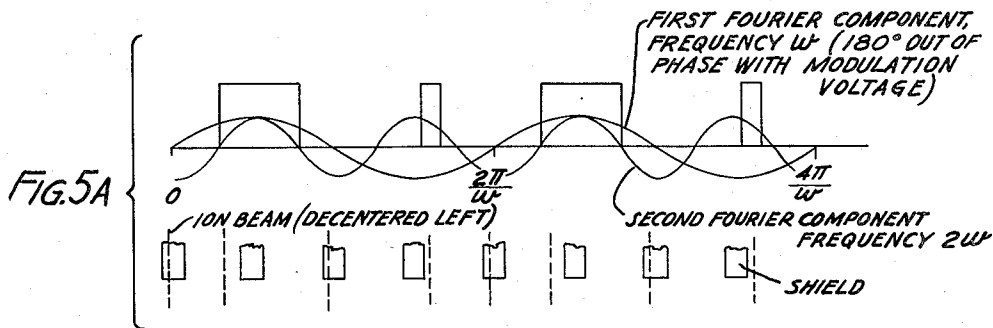
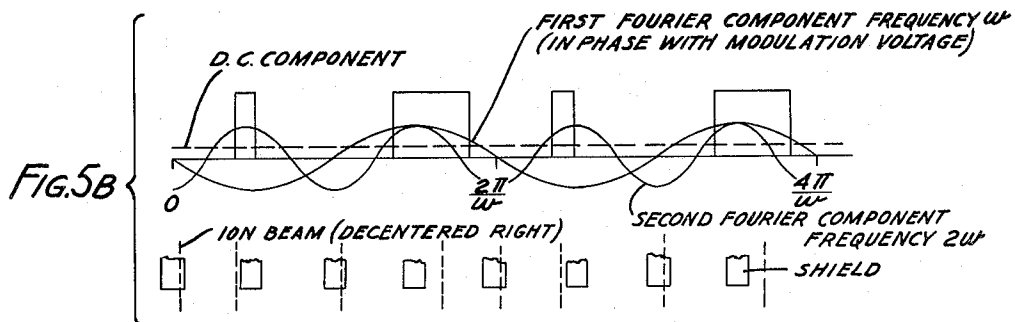
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MASS SPECTROMETRY

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4 Sheets-Sheet 3



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FIG. 6

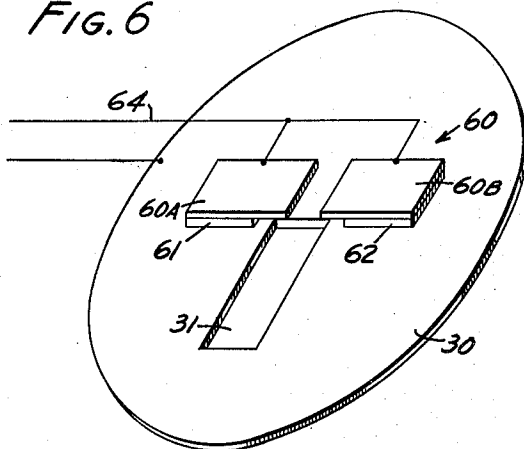
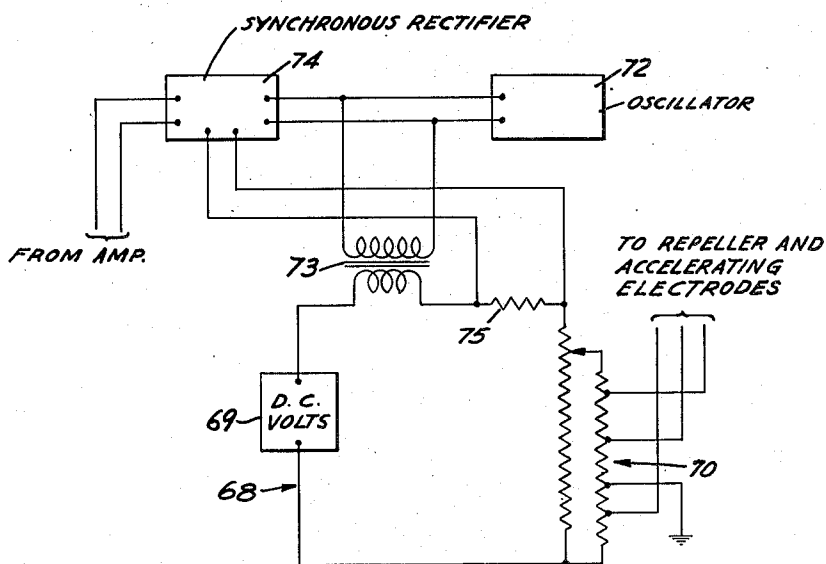


FIG. 7



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2,613,324

MASS SPECTROMETRY

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21 Claims. (Cl. 250—41.9)

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This invention relates to mass spectrometry and to mass spectrometers. More specifically, the invention is directed to improvements in the method of stabilizing ion beams and to apparatus for carrying out the improved method.

A mass spectrometer is an analytical instrument for sorting and measuring ions. Ordinarily, it includes an ionization chamber in which molecules of the sample to be analyzed are bombarded with a stream of electrons to convert them into ions. The ions formed are expelled from the ionization chamber by one or more repeller electrodes and are propelled, by so-called propelling or accelerating electrodes, into and through an analyzer chamber. The analyzer chamber frequently takes the form of a curvilinear enclosure, say a tube. During passage through the chamber, the heterogeneous beam of ions is subjected to a transverse electrical or magnetic field, or both, to separate it into separate diverging ion beams, each of which is composed of ions of a given mass-to-charge ratio which differs from the mass-to-charge ratio of the ions forming the other beams.

The diverging beams may be successively focussed through an exit or resolving slit in a terminal electrode onto a collector electrode. Alternatively, a single one of the ion beams may be continuously focussed on the resolving slit to the exclusion of the other beams. In either event, the focussing of the ion beam or beams is achieved by adjustment of the potential applied to the accelerating electrodes. The current produced by ion discharge at the collector electrode is indicative of the amount of ions in the particular beam and hence constitutes a measure of the partial pressure of the molecules (from which the ions were derived) in the sample being analyzed.

As indicated above, it may be expedient to focus the mass spectrometer on a single mass peak or step-wise on two or more mass peaks rather than sweeping the diverging ion beams successively across the resolving slit. Such a "fixed focus" instrument is used for continuous monitoring where a continuous concentration of a single constituent in a sample stream is sought, in leak detection where the presence of an added contaminant is detected as it appears in the atmosphere surrounding the vessel under investigation, and generally under any circumstances in which a single component or pre-selected group of components is to be measured.

For accurate analysis with a fixed-focus mass spectrometer, it is important that the particular ion beam under investigation be at all times

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centered on the resolving slit. Any appreciable deflection of the subject beam from a centered position will affect the apparent intensity of the beam and hence, result in erroneous analysis. Since the factors which govern the position of the beam are in a typical instrument, the transverse magnetic field and the accelerating voltage, deviation of either of these variables from a pre-selected fixed value will result in displacement of the beam from a centered position.

It has been proposed to stabilize the accelerating voltage against deviations from a pre-selected value by means of a voltage-dropping network wherein a fraction of the accelerating voltage is compared with the voltage output of a standard cell. Any variation in proportionality between the fraction and the standard voltage is balanced automatically by a servo-motor or other means acting on the voltage source supplying the accelerating electrodes. However, the accuracy of such a system depends upon a resistance divider network, the long-term stability of which is questionable. Moreover, the possibility of loss of focus due to temperature sensitivity, variations in power supply to an electromagnet, or aging of a permanent magnet is in no way accounted for in such a voltage-dropping network.

We have developed a method for holding a given ion beam centered on the resolving slit which automatically compensates for fluctuations in the accelerating voltage and also variations in the strength of the magnetic field. The invention contemplates in a method of mass spectrometry which comprises ionizing a sample to be analyzed, propelling the ions by means of a D. C. accelerating potential into an analyzer region, subjecting the ions in the analyzer region to a transverse magnetic field to separate them into individual ion beams, focussing one of said ion beams through a resolving slit, and measuring the current developed by discharge of the beam, the improvement comprising superimposing on the D. C. accelerating potential an A. C. component to cause the ion beam to oscillate transversely with respect to the resolving slit and with an amplitude less than the width of the slit, detecting uncentered oscillation of the beam and adjusting the accelerating voltage to restore centered oscillation.

The invention also includes one form of apparatus for carrying out this method, which comprises in a mass spectrometer having an analyzer chamber, ionization chamber, accelerating electrodes, a source of D. C. voltage connected to develop an accelerating potential on the accelerating electrodes, means for establishing a

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transverse magnetic field in the analyzer chamber, a collector electrode, and a terminal electrode having a resolving slit through which an ion beam is focussed on the collector electrode, the combination comprising a source of A. C. voltage connected to impress an A. C. component on the accelerating electrodes to oscillate the ion beam transversely with respect the resolving slit, means for developing an A. C. signal responsive to uncentered oscillation of the ion beam, and means operative to vary the voltage applied from the D. C. source to the accelerating electrodes responsive to said A. C. signal to restore the beam to a centered position.

The invention will be more clearly understood by reference to the following details description taken in conjunction with the accompanying drawing in which:

Fig. 1 is a diagram of a mass spectrometer in accordance with the invention, showing one means of varying the accelerating voltage responsive to an A. C. signal developed by an oscillating beam.

Fig. 2 is an enlarged isometric view of the terminal electrode showing one means of developing an A. C. signal responsive to oscillation of an ion beam;

Fig. 3 is a sectional elevation taken on the line 3-3 of Fig. 2;

Figs. 4, 4A, 4B are diagram, respectively, of the A. C. signal when the mean ion beam position is centered on the resolving slit, when the ion beam is centered to the left of the resolving slit, and when the ion beam is centered to the right of the resolving slit, in each case the amplitude of beam oscillation being such that no A. C. signal is developed by oscillation of a centered beam;

Figs. 5, 5A and 5B are diagrams illustrating the A. C. signal developed by an oscillating ion beam, the mean position of which is centered on, to the left of, and to the right of the center of the resolving slit, respectively, when the amplitude of oscillation is such that an A. C. signal is developed by a centered beam;

Fig. 6 is an isometric view of the terminal electrode showing an alternative means of developing an A. C. signal responsive to oscillation of an ion beam; and

Fig. 7 is a circuit diagram of the voltage supply circuit of the mass spectrometer of Fig. 1 showing an alternative means for varying the accelerating voltage responsive to an A. C. signal developed by an oscillating ion beam.

The mass spectrometer shown diagrammatically in Fig. 1 includes a pair of accelerating electrodes 10, 11 and a repeller electrode 12. A gas sample to be analyzed is introduced into the region between the repeller electrode and the first accelerating electrode 10 and is bombarded by an electron beam 13 to ionize the molecules. Ions thus formed are expelled through a slit 10A in the first accelerating electrode by application of a positive potential to the repeller electrode. The expelled ions are accelerated between the electrodes 10 and 11 and are expelled through slit 11A in the electrode 11 by means of a potential impressed between the two accelerating electrodes.

Voltage is supplied to the repeller and accelerating electrodes from a voltage supply circuit 14, including a D. C. voltage source 15 connected in series with a slidewire resistor 16. Resistor 16 is tapped by a slider 17 which is connected through a second slide-wire resistor 18 to the

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positive side of the D. C. source 15. The resistor 18 is grounded at 20 adjacent the end thereof remote from slider 17. A lead 22 connects the repeller electrode to resistor 18 on the positive side of ground 20 and leads 23, 24 connect the two accelerating electrodes 10, 11, respectively, to spaced points on the resistor 18 on the negative side of ground 20. This arrangement represents a conventional voltage supply circuit for a fixed-focus mass spectrometer wherein any change in the voltage delivered from the source or applied across resistor 18 results in proportional change in the voltage applied to the two accelerating electrodes and the repeller.

The ions issuing from slit 11A in the electrode 11 are caused to pursue a curved path as indicated by the ion beam 26, the curved path being produced by a transverse magnetic field developed by magnet 27. A terminal electrode 30 is placed in the path of the ion beam after it has travelled through a 180° arc, and is provided with a resolving slit 31 through which a single beam of ions of a given mass-to-charge ratio may be focussed. A collector electrode 32 is disposed behind the terminal electrode and ions passing through the resolving slit 31 discharge on the collector electrode. The collector electrode is electrically connected to a D. C. amplifier 34, which in turn is connected to a sensing means 36 which may be a recorder or other sensing device. The current developed at the collector electrode by discharge of a particular ion beam is amplified in the amplifier 34 and recorded or otherwise sensed in the sensing means 36. To this extent, the operation of the mass spectrometer of Fig. 1 is typical of so-called fixed-focus instruments.

In accordance with one form of the present invention as illustrated in Figs. 1-3, a source 38 of A. C. voltage is coupled through a switch 38A and a transformer 39 to the D. C. voltage supply circuit 14 to superimpose on the D. C. voltage applied to the accelerating electrodes a comparatively small A. C. component of a frequency ω when the switch 38A is closed.

A sensor electrode 42 is mounted adjacent and conveniently to the terminal electrode 30 at one end of the revolving slit 31 and is insulated from the terminal electrode. A shield 44 is spaced from the front of the sensor electrode 42 and may be grounded to the terminal electrode 30. The shield is approximately the width of the ion beam so that an ion beam centered on the resolving slit will not strike the sensor electrode 42. The sensor electrode 42 is connected to an A. C. amplifier 45, the other input terminal of which is conveniently connected to ground or to terminal electrode 30 (as shown).

A reversible motor 46 is mechanically connected to slider 17 of the D. C. voltage supply circuit in such a fashion that operation of the motor will adjust the position of slider 17 with respect to the slidewire 16. One coil 46A of the motor is connected to the source 38 of A. C. voltage and the other coil 46B of the motor is connected to the output of the A. C. amplifier 45.

The arrangement of the terminal electrode, sensor electrode and shield is best illustrated in the isometric view of Fig. 2 and the sectional elevation of Fig. 3. Referring to these figures, the electrode 30 is provided with an elongated rectangular resolving slit 31. Sensor electrode 42 is mounted across one end of the slit and conveniently directly to electrode 30 by means of in-

ulating spacers 48, 49. A shield 44, conveniently comprising a conductive metal strip, is rigidly affixed at 44A to the electrode 30 and offset therefrom to project across and above the central part of sensor electrode 42. The end of the shield overlying the sensor electrode is approximately the same width as the ion beam plus the peak-to-peak amplitude of beam oscillation, and is in vertical alignment with the resolving slit, such that the part of the beam which strikes shield 44 is centered on the shield when the portion of the beam which passes through slit 31 is centered in the slit. It may or may not result that shield 44 is centered above slit 31 since the ion beam may be more or less curved. The terminal electrode 30 and the sensor electrode 42 are connected by leads 30A and 42A, respectively, to amplifier 45 (shown in Fig. 1). Alternatively, the terminal electrode and amplifier may be grounded.

The operation of the apparatus illustrated in Figs. 1-3 is best described with relation to the diagrams of Figs. 4, 4A, 4B. The voltage output of the A. C. source is held at such a value that the resultant oscillation of the ion beam has an amplitude just less than the width of the shield. Hence, if the beam is perfectly centered on the resolving slit, oscillation thereof will be within the region defined by the shield 44 (see Fig. 2), and the beam will not fall upon the sensor electrode 42 in any part of the oscillating cycle. This condition is illustrated in Fig. 4 wherein the base line 52 extends through two complete cycles of the A. C. component having a frequency ω . Beneath the base line in the figure, the relationship of the ion beam to the exit slit 31 and shield 44 is illustrated through various stages in the oscillating cycle. Thus at zero amplitude, the beam is centered on the resolving slit and shield. A quarter of a cycle later it has shifted toward the lefthand edge of the shield. A quarter of a cycle later it has returned to the centered or zero amplitude position. Thereafter it proceeds through the other half of the cycle, shifting toward the right of the shield and again back to the zero or centered position to complete the cycle. Since the amplitude of oscillation of the beam is less than the width of the shield, it does not strike the sensor electrode and no signal is produced.

In Fig. 4A, the same type of chart illustrates the conditions existing when the beam is out of focus to the left of the center of the resolving slit. At zero amplitude, the beam is adjacent the left edge of the resolving slit but still on the shield, and a quarter of a cycle later it has shifted to the left, falling outside the resolving slit and shield. In this position, the tail end of the beam strikes the sensor electrode and a pip 54 is developed across leads 30A and 42A and delivered to the A. C. amplifier 45. A quarter of a cycle later the beam shifts back to its zero position, thereafter shifting to the right of center of the resolving slit and at the completion of a cycle, back to the zero amplitude position adjacent the lefthand edge of the shield. In this manner a signal is developed between the sensor and terminal electrodes for each cycle of oscillation, the pips 54, 54A on base line 52 indicating the relationship of these signals to the beam position.

The same kind of analysis is carried out in Fig. 4B showing the signal developed when the mean beam position or zero amplitude position is to the right of center of the resolving slit and

shield. Under these conditions a single pulse is developed during each cycle of oscillation, illustrated as the pips 56, 56A on the base line 52. However, the signal developed when the beam is to the right of center is opposite in phase to the signal developed when the beam to the left of center, although both signals have a fundamental frequency of ω where the frequency of the voltage output of the A. C. source is ω . Under these conditions, the output of the A. C. amplifier impressed across motor coil 46B (Fig. 1), will be of the same frequency as the signal impressed across motor coil 45A from the A. C. source 38. The motor will thus be energized in the direction, depending upon the phase of the output of the A. C. amplifier, to adjust the slider 17 in the appropriate direction to return the beam to a centered position.

The foregoing discussion describes the case in which the shield 44 has width equal to the beam width plus the peak-to-peak modulation amplitude. A second situation which may arise either accidentally or deliberately in practice is one in which the shield width is of the same order as the beam width, being less than the beam width plus the peak-to-peak amplitude. In this condition, the results are as shown in Figs. 5, 5A, 5B, which show the A. C. signal developed on electrode 42 responsive to the three conditions of beam position, i. e., centered, decentered left and decentered right respectively. In each of these situations, a signal of frequency 2ω and higher is developed on electrode 42, but only in the decentered cases 5A, 5B does this signal contain a component of frequency ω which is required to drive the motor 46. It is thus noted that although the superficial appearance of the signal depends strongly on the relative widths of the beam, the shield, and the modulation amplitude, the actual operation of the invention is insensitive to changes in these parameters within wide limits.

It is readily apparent that the function of shield 44 is simply to prevent current of frequency ω from being collected on sensing electrode 42 when the beam is properly centered, and this function may be served equally well by simply cutting away part or all of the central portion of electrode 42, as shown in Fig. 6, which is an isometric view similar to Fig. 2.

In the modification shown in Fig. 6, a sensor electrode 60 is divided centrally into segments 60A, 60B. The electrode segments are mounted on terminal electrode 30 with their adjoining edges spaced on opposite sides of the longitudinal axis of resolving slit 31. The sensor electrode segments are insulated from the terminal electrode by insulators 61, 62, respectively, and are connected by a single lead 64 to the amplifier (not shown). The intervening space between the segments performs the same function as shield 44 (Fig. 2).

An important advantage of the invention lies in the fact that under no condition is it necessary to permit the central part of the ion beam to be impaired in any way. Accordingly, the practice of the invention permits detection and correction of a decentered beam long before the degree of decentering is large enough that the beam strikes an edge of slit 31 and impairs the accuracy of the analysis by so doing.

The method and apparatus of the present invention thus has the fundamental and very important advantage that the D. C. output of the collector electrode 32 is uninterrupted and

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the further advantage that the beam centering operation may be carried on continuously rather than periodically. Since the outer or tail edge of the beam is used to develop the centering signal, the intensity of the discharge at the collector electrode is not reduced since normal practice is to discard this portion of the ion beam. Moreover, since the amplitude of the oscillation of the beam is less than the width of the ion slit, the discharge signal developed at the collector electrode is not affected so long as the ion beam is centered on the slit. If either of the critical variables, to-wit, accelerating voltage or magnetic field strength, vary from a pre-selected value, the beam focus will shift in one direction or another from center position and will immediately develop a signal at the sensor electrode of the type shown in Figs. 4A or 4B, 5A or 5B. The reaction of the centering circuit will be substantially instantaneous to effect a compensatory adjustment of the accelerating voltage to return the beam to a centered position. For this reason, any error introduced into the collector electrode discharge signal, as a consequence of variation in beam focus, will be of insignificant duration.

In the foregoing description, a servo-motor has been illustrated and described as one means of adjusting the accelerating voltage responsive to production of an A. C. signal of the same frequency as the beam modulation voltage. Another means of accomplishing this adjustment is shown in the circuit diagram of Fig. 7, which includes a voltage supply circuit 68 substantially similar to the circuit 14 of Fig. 1. The circuit 68 includes a D. C. voltage source 69 and a voltage divider network 70 connected to the accelerating electrodes (not shown). An oscillator 72 is connected through a transformer 73 to apply an A. C. voltage to the circuit. A synchronous rectifier 74 is connected to receive the signal from the A. C. amplifier (not shown) and a synchronizing signal from oscillator 72. When the input signal has the same frequency as the synchronizing signal, the rectifier which is connected to circuit 68 across a resistor 75, develops a D. C. voltage across the resistor the polarity of which is sensitive to the phase of the input signal. Hence, the voltage across the divider network 70 is varied responsive to the signal developed by an off centered oscillating beam and in a direction depending on the phase of the signal.

The invention has been described in some detail with relation to a mass spectrometer operating on only a pre-selected mass peak. Such an instrument is used for example, in leak detection where the only component of interest is a foreign gas, say helium, introduced into the atmosphere in a vessel under test and detected in the atmosphere surrounding the vessel. However, continuous monitor mass spectrometers are frequently set up to focus on a number of pre-selected peaks by varying the accelerating voltage in a step-wise fashion. This type of operation distinguishes from a continuous scan mass spectrometer in which the accelerating voltage is varied gradually over a given range to sweep a part or all of the mass spectra of a given sample successively across the resolving slit. When the accelerating voltage is varied step-wise in a continuous monitor instrument to monitor two or more components, the beam centering method and apparatus of the invention is useful to hold all of the successive beams in a centered position.

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The invention has been further described with respect to its operation on a single mass peak wherein the mass peak of interest is also used as the basis for centering the apparatus. This is not a necessary limitation of the apparatus or the method since it may be frequently desirable to center on a relatively stronger peak even though such a relatively stronger peak is of no interest in the analysis. This is simply accomplished by placing a stepper switch in the D. C. supply circuit 14, which may be manually or automatically operated periodically to shift the accelerating voltage to that required to focus the stronger peak on the resolving slit. Such a stepper switch in the D. C. supply circuit is conveniently ganged to the switch 38A in the A. C. voltage supply circuit so that an A. C. component is impressed on the D. C. supply circuit only when the reference peak is focussed on the resolving slit. Of course, if the peak of interest is also used as the reference peak, such a stepper switch is not necessary in the D. C. supply circuit and the A. C. component may be impressed on the D. C. voltage continuously.

Application of the invention is not limited to the particular apparatus illustrated as preferred means for accomplishing the improved operation. It is entirely practical to produce the desired oscillation of the ion beam by means other than impression of an A. C. voltage component on the accelerating electrodes. For example, auxiliary electrodes arranged transversely with respect to the path of ion travel will induce the same type of oscillation when energized with an A. C. voltage. Alternatively, the magnetic field may be varied in a rhythmic manner to accomplish the same purpose. At the same time, the correction applied by motor 46 (Fig. 1), by the synchronous rectifier 74 (Fig. 7) or by other means sensitive to the Fourier component of the sensor electrode output of the frequency of the beam oscillation, is not restricted to the adjustment of the accelerating potentials. Variation in the magnetic field strength or an auxiliary field developed by deflecting electrodes will also accomplish the desired adjustment of the beam position with respect to the exit slit.

We claim:

1. In mass spectrometry involving ionizing a sample to be analyzed, propelling the ions by means of a D. C. accelerating potential into an analyzer region, subjecting the ions in the analyzer region to a transverse magnetic field to separate them into individual ion beams, focusing one of said ion beams through a resolving slit, discharging the beam passing through the resolving slit, and sensing the current developed by discharge of the beam, the improvement comprising superimposing on the D. C. accelerating potential an A. C. component to cause the ion beam to oscillate transversely with respect to the resolving slit and with an amplitude less than that which would cause the beam to strike a side edge of the slit, detecting uncentered oscillation of the beam and adjusting the accelerating voltage to restore centered oscillation.

2. In mass spectrometry involving ionizing a sample to be analyzed, propelling the ions by means of a D. C. accelerating potential into an analyzer region, subjecting the ions in the analyzer region to a transverse magnetic field to separate them into individual ion beams, focusing one of said ion beams through the resolving slit, and sensing the current developed by discharge of the beam, the improvement comprising

periodically superimposing on the D. C. accelerating potential an A. C. component to cause the ion beam to oscillate transversely with respect to the resolving slit and with an amplitude less than that which would cause the beam to strike a side edge of the slit, detecting uncentered oscillation of the beam and adjusting the accelerating voltage to restore centered oscillation.

3. In mass spectrometry involving ionizing a sample to be analyzed, propelling the ions by means of a D. C. accelerating potential into an analyzer region, subjecting the ions in the analyzer region to a transverse magnetic field to separate them into individual ion beams, focusing one of said ion beams through a resolving slit, discharging the beam passing through the resolving slit, and sensing the current developed by discharge of the beam, the improvement comprising superimposing on the D. C. accelerating potential an A. C. component to cause the ion beam to oscillate transversely with respect to the resolving slit and with an amplitude less than that which would cause the beam to strike a side edge of the slit, detecting uncentered oscillation of the beam and adjusting the accelerating potential responsive to the detected uncentered oscillation of the beam to restore centered oscillation.

4. In mass spectrometry involving ionizing a sample to be analyzed, propelling the ions by means of a D. C. accelerating potential into an analyzer region, subjecting the ions in the analyzer region to a transverse magnetic field to separate them into individual ion beams, focusing one of said ion beams through a resolving slit in a terminal electrode, discharging the beam passing through the resolving slit, and sensing the current developed by discharge of the beam, the improvement comprising periodically superimposing on the D. C. accelerating potential an A. C. component to cause the ion beam to oscillate transversely with respect to the resolving slit and with an amplitude less than that which would cause the beam to strike a side edge of the slit, whereby the oscillating beam generates an A. C. signal when it is not centered on the resolving slit, and adjusting the accelerating potential responsive to such A. C. signal to restore centered oscillation.

5. In mass spectrometry involving ionizing a sample to be analyzed, propelling the ions by means of a D. C. accelerating potential into an analyzer region, subjecting the ions in the analyzer region to a transverse magnetic field to separate them into individual ion beams, focusing one of said ion beams through a resolving slit, discharging the beam passing through the resolving slit, and sensing the current developed by discharge of the beam, the improvement comprising continuously superimposing on the D. C. accelerating potential an A. C. component to cause the ion beam to oscillate transversely with respect to the resolving slit and with an amplitude less than that which would cause the beam to strike a side edge of the slit, whereby the oscillating beam generates an A. C. signal when it is not centered on the resolving slit, and adjusting the accelerating potential responsive to such A. C. signal to restore centered oscillation.

6. In a mass spectrometer having an analyzer chamber, ionization chamber, accelerating electrodes, a source of D. C. voltage connected to impress an accelerating potential on the accelerating electrodes, means for establishing a transverse magnetic field in the analyzer chamber, a

collector electrode, and a terminal electrode having a resolving slit through which an ion beam is focussed on the collector electrode, the combination comprising a source of A. C. voltage connected to impress an A. C. component on the accelerating electrodes to cause oscillation of the ion beam, means independent of said collector electrode, to detect uncentered oscillation of said beam and to develop an A. C. signal responsive to such uncentered oscillation, and means operative to vary the voltage applied from the D. C. source to the accelerating electrodes responsive to said A. C. signal.

7. In a mass spectrometer having an analyzer chamber, ionization chamber, accelerating electrodes, a source of D. C. voltage connected to impress an accelerating potential on the accelerating electrodes, means for establishing a transverse magnetic field in the analyzer chamber, a collector electrode, and a terminal electrode having a resolving slit through which an ion beam is focussed on the collector electrode, the combination comprising a source of A. C. voltage connected to impress an A. C. component on the accelerating electrodes to oscillate the ion beam transversely with respect to the resolving slit, means independent of said collector for developing an A. C. signal responsive to uncentered oscillation of the beam, and means operative to vary the voltage applied to the accelerating electrodes responsive to said A. C. signal to restore the beam to a centered position.

8. In a mass spectrometer having an analyzer chamber, ionization chamber, accelerating electrodes, a source of D. C. voltage connected to impress an accelerating potential on the accelerating electrodes, means for establishing a transverse magnetic field in the analyzer chamber, a collector electrode, and a terminal electrode having a resolving slit through which an ion beam is focussed on the collector electrode, the combination comprising a source of A. C. voltage connected to impress an A. C. component on the accelerating electrodes to cause oscillation of the ion beam, the source of A. C. voltage being adapted to produce an A. C. component at the accelerating electrodes of such magnitude as to cause beam oscillation of an amplitude just less than the width of said resolving slit, means cooperating with said terminal electrode and independent of said collector electrode to detect uncentered oscillation of said beam and to develop an A. C. signal responsive to such uncentered oscillation, means operative to vary the voltage applied from the D. C. source to the accelerating electrodes responsive to said A. C. signal.

9. In a mass spectrometer having an analyzer chamber, ionization chamber, accelerating electrodes, a source of D. C. voltage connected to impress an accelerating potential on the accelerating electrodes, means for establishing a transverse magnetic field in the analyzer chamber, a collector electrode, and a terminal electrode having a resolving slit through which an ion beam is focussed on the collector electrode, the combination comprising a source of A. C. voltage connected to impress an A. C. component on the accelerating electrodes, a sensor electrode disposed adjacent the terminal electrode on the side opposite the collector electrode, an A. C. amplifier connected to the sensor electrode, means operative to vary the voltage applied from the D. C. source to the accelerating electrodes responsive to the output of said A. C. amplifier.

10. In a mass spectrometer having an analyzer chamber, ionization chamber, accelerating electrodes, a source of D. C. voltage connected to impress an accelerating potential on the accelerating electrodes, means for establishing a transverse magnetic field in the analyzer chamber, a collector electrode, and a terminal electrode having a resolving slit through which an ion beam is focussed on the collector electrode, the combination comprising a source of A. C. voltage connected to impress an A. C. component on the accelerating electrodes, a sensor electrode disposed adjacent one end of said resolving slit in the focussing electrode on the side opposite the collector electrode and insulated from the terminal electrode, an A. C. amplifier connected to the sensor electrode, and means operative to vary the voltage applied from the D. C. source to the accelerating electrodes responsive to the output of said A. C. amplifier.

11. In a mass spectrometer having an analyzer chamber, ionization chamber, accelerating electrodes, a voltage supply circuit connected to impress an accelerating potential on the accelerating electrodes, means for establishing a transverse magnetic field in the analyzer chamber, a collector electrode, and a terminal electrode having a resolving slit through which an ion beam is focussed on the collector electrode, the combination comprising a source of A. C. voltage connected to impress an A. C. component on the accelerating electrodes, a sensor electrode disposed adjacent one end of said resolving slit in the terminal electrode on the side opposite the collector electrode and insulated from the terminal electrode, an electrical shield mounted in front of the sensor electrode and grounded to the terminal electrode, an A. C. amplifier connected to the sensor electrode, and means operative to vary the voltage applied from the D. C. source to the accelerating electrodes responsive to the output of said A. C. amplifier.

12. Apparatus according to claim 11 wherein the sensor electrode is mounted to the terminal electrode adjacent one end of the resolving slit and is spaced from the terminal electrode by insulating spacers.

13. Apparatus according to claim 12 wherein the electrical shield is affixed to the terminal electrode in conductive relationship and is offset outwardly to overlie the central portion of the sensor electrode without making electrical connection thereto.

14. Apparatus according to claim 11 wherein the means operative to vary the voltage comprises a two-phase reversible motor mechanically connected to said source of D. C. voltage, one coil of the motor being connected to the source of A. C. voltage, and the other coil of the motor being connected to the A. C. amplifier.

15. Apparatus according to claim 11 wherein the means operative to vary the voltage comprises a synchronous rectifier connected to receive the output signal from said A. C. amplifier as an input signal and a signal from said A. C. source as a synchronizing signal and to develop a voltage in said voltage supply circuit, the polarity of which is sensitive to the phase of said A. C. amplifier output signal.

16. In a mass spectrometer having an analyzer chamber, ionization chamber, accelerating electrodes, a source of D. C. voltage connected to impress an accelerating potential on the accelerating electrodes, means for establishing a transverse magnetic field in the analyzer cham-

ber, a collector electrode, and a terminal electrode having a resolving slit through which an ion beam is focussed on the collector electrode, the combination comprising a source of A. C. voltage connected to impress an A. C. component on the accelerating electrodes, a sensor electrode disposed adjacent one end of said resolving slit in the focussing electrode on the side opposite the collector electrode and insulated from the terminal electrode, the sensor electrode being non-receptive to ion discharge in the region overlying an extension of the longitudinal axis of the resolving slit.

17. Apparatus according to claim 16 wherein the sensor electrode comprises two physically separated electrically connected segments spaced from each other on opposite sides of the longitudinal axis of the resolving slit.

18. In a mass spectrometer having an analyzer chamber, ionization chamber, accelerating electrodes, a source of D. C. voltage connected to impress an accelerating potential on the accelerating electrodes, means for establishing a transverse magnetic field in the analyzer chamber, a terminal electrode having a resolving slit, a sensor electrode disposed in front of the terminal electrode transversely with respect to said ion slit, and means preventing the ion discharge in an area defined by said sensor electrode and overlying the longitudinal axis of the slit and narrower than the slit, the method of holding an ion beam in focus on the center of said slit comprising impressing an A. C. potential on said accelerating electrodes to oscillate the ion beam, maintaining the magnitude of said A. C. potential such that the amplitude of beam oscillation plus the average width of the beam is greater than the transverse width of said area and less than the transverse width of said resolving slit.

19. In a mass spectrometer having an analyzer chamber, ionization chamber, accelerating electrodes, a source of D. C. voltage connected to impress an accelerating potential on the accelerating electrodes, means for establishing a transverse magnetic field in the analyzer chamber, a terminal electrode having a resolving slit, a sensor electrode disposed in front of the terminal electrode transversely with respect to said ion slit, and means preventing the ion discharge in an area defined by said sensor electrode and overlying the longitudinal axis of the slit and narrower than the slit, the method of holding an ion beam in focus on the center of said slit comprising impressing an A. C. potential on said accelerating electrodes to oscillate the ion beam, maintaining the magnitude of said A. C. potential such that the amplitude of beam oscillation plus the average width of the beam is less than the transverse width of said area.

20. In mass spectrometry involving ionizing a sample to be analyzed, subjecting the ions to a combination of electric and magnetic fields to separate the ion beam into a plurality of divergent beams each having a characteristic mass-to-charge ratio, and passing one such divergent beam through a resolving slit into a collector, the improvement which comprises causing one of said beams to oscillate transversely with respect to the resolving slit, discharging a part of the oscillating beam prior to its reaching the resolving slit, and adjusting the position of the beam with respect to the slit responsive to the Fourier component of the discharge signal the frequency of which is the same as the frequency at which the beam is oscillated.

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21. In a mass spectrometer having an analyzer chamber, ionization chamber, accelerating electrodes for propelling ions from the ionization chamber, means for establishing a transverse magnetic field across the analyzer chamber, a collector electrode, and a terminal electrode between the analyzer chamber and collector electrode and having a resolving slit therein, the combination comprising means for oscillating an ion beam transversely with respect to said resolving slit, an auxiliary collector electrode being in-

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sensitive to a beam passing centrally through the resolving slit, and means operative to adjust the position of the beam responsive to the Fourier component of the auxiliary electrode output which is of the same frequency as the frequency of oscillation of the ion beam.

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No references cited.