

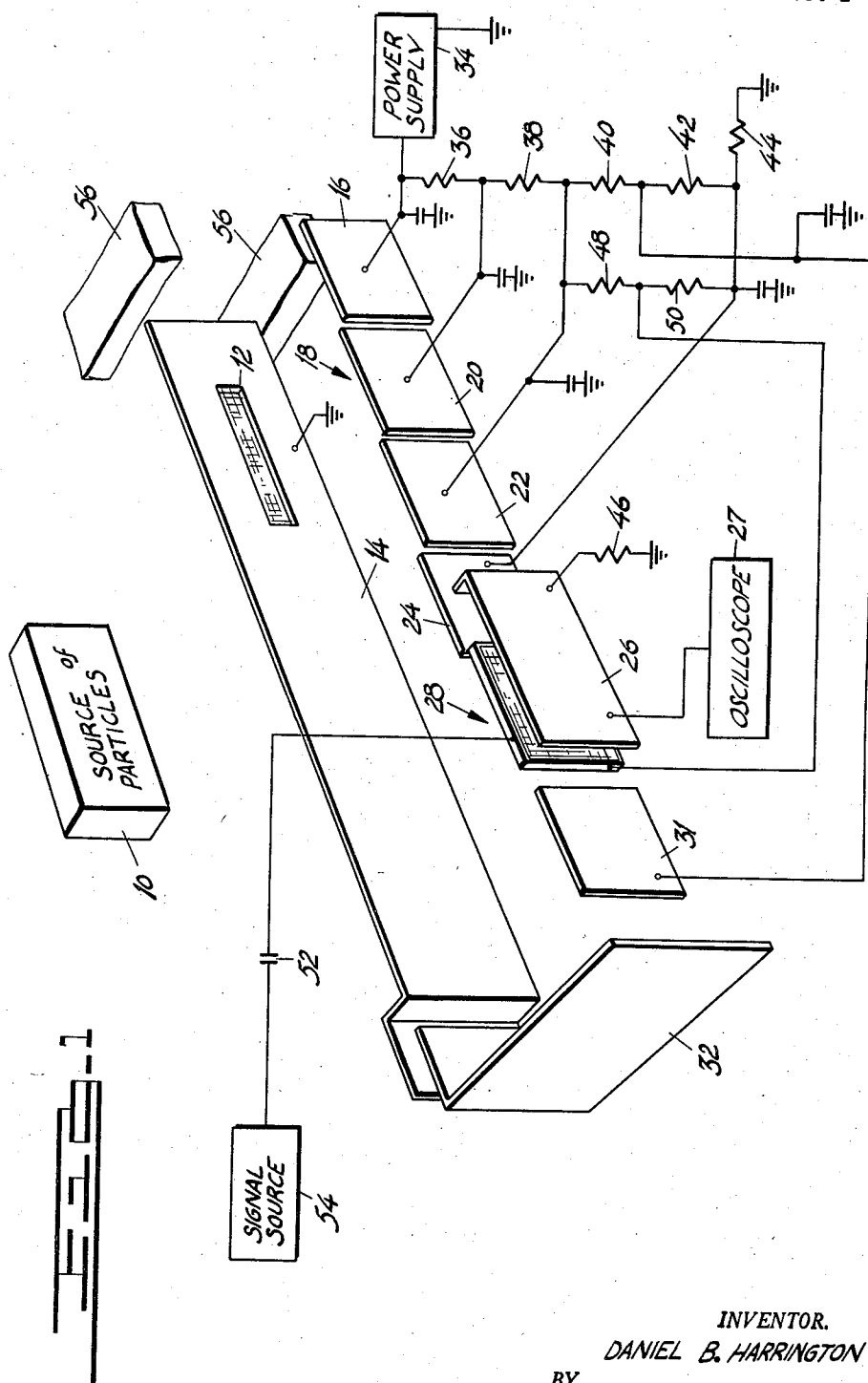
June 2, 1959

D. B. HARRINGTON
ELECTRON MULTIPLIER

2,889,461

Filed Aug. 10, 1953

4 Sheets-Sheet 1



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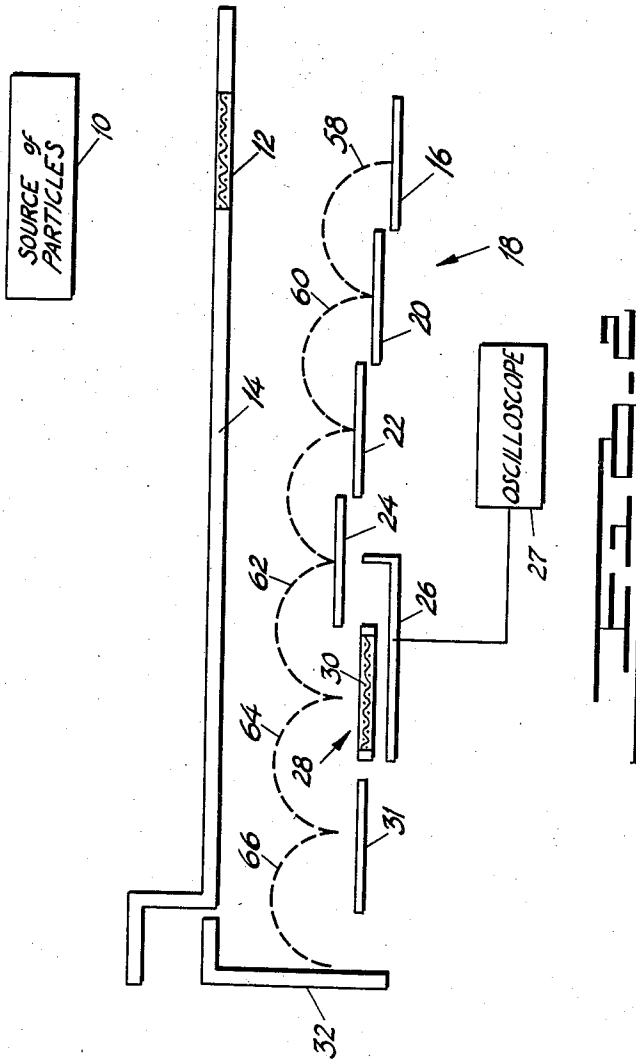
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4 Sheets-Sheet 2



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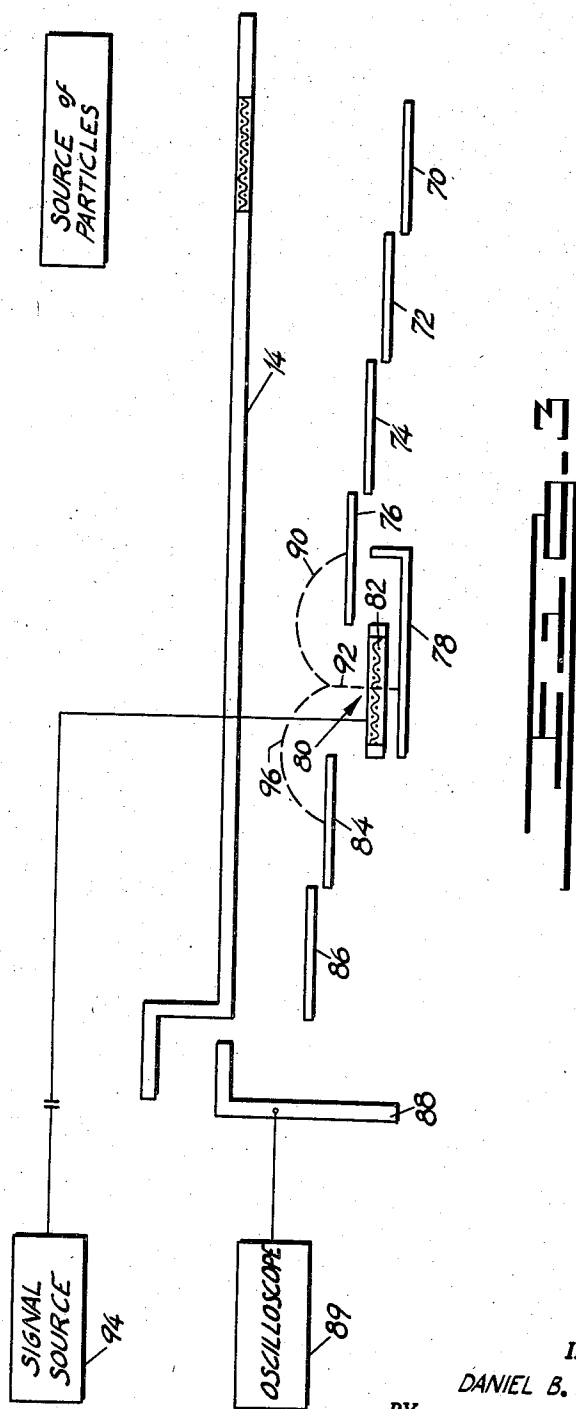
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4 Sheets-Sheet 3



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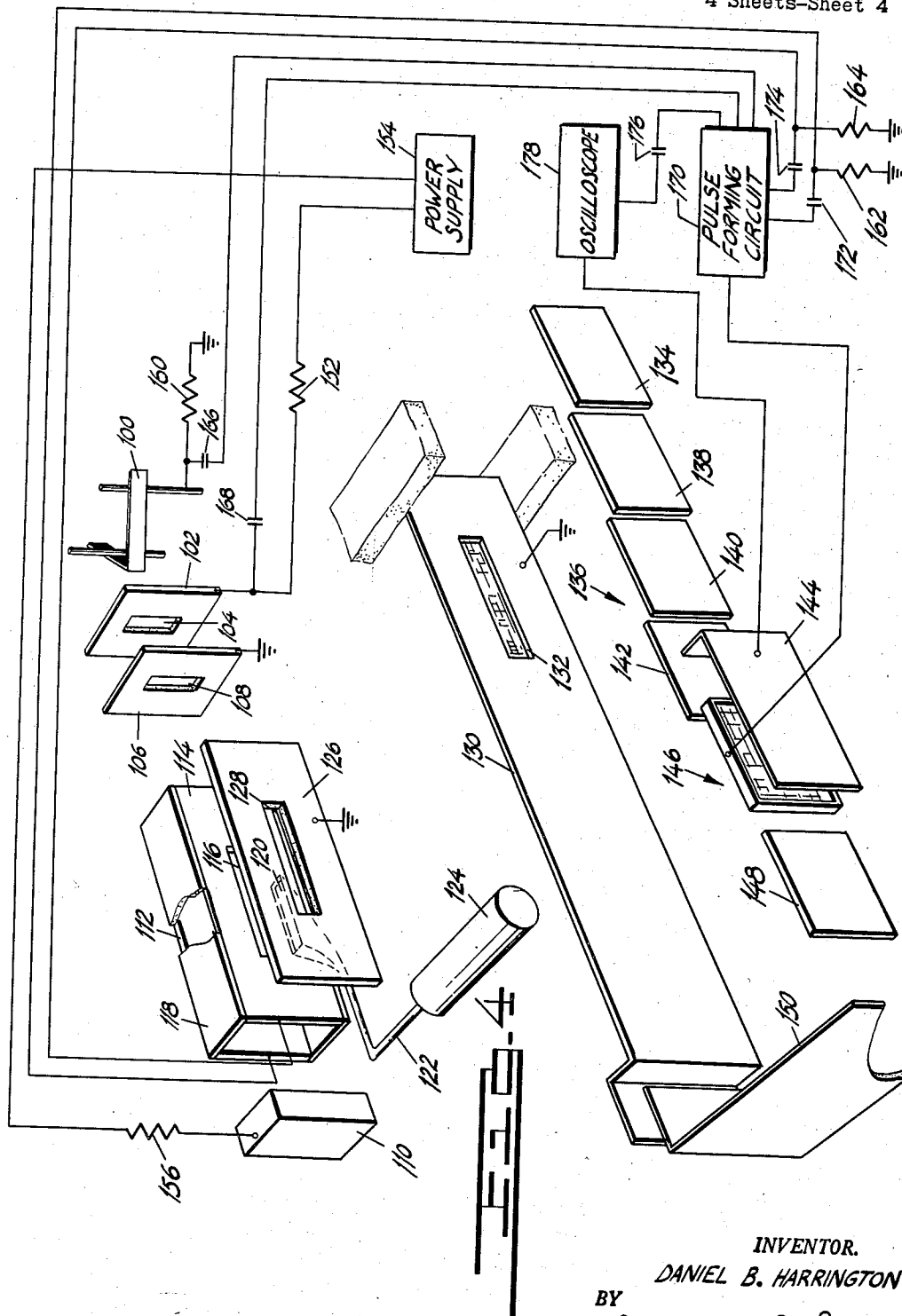
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4 Sheets-Sheet 4



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2,889,461

ELECTRON MULTIPLIER

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Application August 10, 1953, Serial No. 373,333

11 Claims. (Cl. 250—41.9)

This invention relates to electron multipliers and more particularly to electron multipliers for accurately producing output signals of great strength corresponding to the pattern of relatively weak input signals.

Electron multipliers are often utilized to amplify electrical signals. Such multipliers include a plurality of plates which are so disposed relative to one another that each plate receives electrons from a preceding plate and produces an increased number of electrons. By utilizing a number of plates in a multiplier, amplitudes approaching one million times or more the strength of an input signal can be produced.

Electron multipliers now in use are able to utilize only signals formed by a plurality of particles, such as ions or electrons. The number of particles in the stream at any instant determines the strength of the stream. These particles are introduced to the first plate in the multiplier for conversion by the plate into a stream of electrons corresponding in strength to the number of particles. Since it is difficult to produce a stream of particles having a variable strength, the electron multipliers now in use are adapted only for specialized applications.

This invention provides an electron multiplier for producing a steady stream of particles and for utilizing a gate to control the number of electrons flowing to an output plate in the multiplier at any instant. The gate is formed by a plurality of spaced wires positioned in contiguous relationship to one of the plates in the multiplier. An electrical signal is applied to the gate to control the number of electrons flowing past the gate to the output electrode at any instant. Since the electrical signal applied to the gate can be easily produced by a modulator or other type of circuit, the electron multiplier is available for a wide variety of uses.

An object of this invention is to provide an electron multiplier for producing strong output signals which are accurately indicative of the amplitude of an input signal at any instant.

Another object is to provide an electron multiplier of the above character which utilizes an input signal to modulate a constant stream of particles so that a variable stream of electrons can be received at an output plate in the multiplier.

A further object is to provide a spectrometer of the above character which utilizes a gate formed from a plurality of spaced wires to control the flow of electrons to an output plate in the multiplier.

Still another object is to provide an electron multiplier of the above character for use in a mass spectrometer to detect ions of a particular mass.

A still further object is to provide an electron multiplier of the above character for use in a mass spectrometer to provide an output signal only when ions of a particular mass are present in an unknown mixture.

Other objects and advantages will be apparent from a detailed description of the invention and from the appended drawings and claims.

In the drawings:

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Figure 1 is a schematic view, partly in block form and partly in perspective, of an electron multiplier constituting one embodiment of this invention;

Figure 2 is a plan view schematically illustrating the operation of the electron multiplier shown in Figure 1;

Figure 3 is a plan view of an electron multiplier constituting another embodiment of the invention; and

Figure 4 is a somewhat schematic view, partly in block form and partly in perspective, of a mass spectrometer which utilizes the electron multiplier shown in Figures 1 and 2.

In the embodiment of the invention shown in Figures 1 and 2, a source 10 is adapted to emit a stream of particles. The source 10 may be an ion source for a mass spectrometer, such as is shown in Figure 3 and as will be disclosed in detail hereafter. The source may emit charged particles, such as ions or electrons.

The source 10 is adapted to emit particles towards a window 12 in an electrode 14 having a relatively large lateral dimension. The window 12 is in turn disposed directly in back of a plate 16 so that the particles from the source 10 will pass through the window and impinge on the plate. The plate 16 forms part of an electron multiplier, generally indicated at 18, which also includes plates 20, 22, 24 and 26.

Each of the plates 16, 20, 22 and 24 are made from a suitable material to secondarily emit electrons when electrons or other particles strike it. For example, the plates may be made from a beryllium copper alloy having approximately 2% by weight of beryllium. The plates may be approximately 0.375 inches wide.

The plates 16, 20, 22, 24 and 26 are positioned in laterally contiguous relationship to one another such that the left extremity of each plate is positioned close to the right extremity of its adjacent plate. Each of the plates 20, 22 and 24 is disposed slightly in back of the plates 16, 20 and 22, respectively, in a progressively staggered relationship. For example, the plate 16 may be positioned approximately 0.225 inch in front of the electrode 14 and the plates 20, 22 and 24 may be approximately 0.200, 0.175 and 0.150 inch away from the electrode 14. The plate 26 is positioned in front of the plate 24. By way of illustration, the plate 26 may be positioned approximately 0.250 inch in front of the electrode 14. An indicator such as an oscilloscope 27 is connected to the plate 26 to indicate the electrons impinging on the plate.

A gate, generally indicated at 28, is positioned in contiguous and substantially parallel relationship to the plate 26. For example, the gate 28 may be positioned approximately 0.075 inch in back of the plate 26. The gate 28 is formed from a plurality of wires 30 spaced at regular intervals from one another. For example, the wires 30 (Figure 2) may be separated by approximately 0.01 inch from one another.

A plate 31 is disposed to the left of the gate 28 in contiguous relationship to the gate. The plate 31 is disposed approximately 0.005 inch in front of the gate 28. As will be disclosed in detail hereinafter, the plate 31 is included not for the purpose of receiving electrons from a preceding plate and emitting a proportionate number of electrons but for the purpose of insuring a substantially constant electric field between the electrode 14 and the plates. A collector 32 has a pair of portions at right angles to each other. One of the portions is laterally aligned with the electrode 14 and is disposed in substantially parallel relationship to the plate 31. The other portion extends towards the plate 31 at a position to the left of the plate.

Direct current voltages are applied to the plates 16, 20, 22, 24 and 26 to produce a substantially constant electric field between the electrode 14 and the plates. Since the electrodes 16, 20, 22, 24 and 26 are positioned at different

distances from the electrode 14, different voltages are applied to the plates to produce a substantially constant electric field.

These voltages are applied to the plates 16, 20, 22, 24, and 26 from a power supply 34 through a resistance network including resistances 36, 38, 40, 42 and 44, the resistance 44 being grounded. For example, voltages of approximately -1,800, -1,600, -1,400, and -1,200 volts are applied to the plates 16, 20, 22 and 24, respectively, and approximately -1,400 volts may be applied to the plate 31 from an appropriate terminal in the resistance network. The plate 26 is connected to a grounded resistance 46 and the electrode 14 is directly grounded.

A biasing voltage is applied to the gate 28 from the common terminal between a pair of resistances 48 and 50 in series with each other and in parallel with the resistances 40 and 42. In the example disclosed above, a voltage of approximately -1,250 volts may be applied to the gate 28. An input signal is also applied to the gate 28 through a coupling capacitance 52 from a signal source 54. The signal from the source 54 may have a repetitive pattern such as a sine wave or it may have a random pattern to simulate a phenomenon such as noise.

A magnetic field as well as an electrical field acts upon the electrons emitted by the plates 16, 20, 22 and 24. The magnetic field is produced in a vertical direction substantially parallel to the faces of the plates. The magnetic field is imposed on the electrons by a pair of pole pieces 56, one positioned above the plates and the other positioned below the plates. In the example disclosed above, a magnetic field of approximately 400 Gauss may be applied by the pole pieces 56.

The ions produced by the source 10 travel through the window 12 in the electrode 14 and impinge upon the plate 16. Because of the particular material from which the plate 16 is made, the plate emits electrons when the particles from the source 10 impinge upon it. The number of electrons emitted by the plate 16 is dependent upon the number of ions impinging upon the plate, among other factors.

The electrons emitted by the plate 16 are subjected to the combined action of the electrical field between the electrode 14 and the plate and the magnetic field between the pole pieces 56. This causes the electrons to travel in a curved path indicated in broken lines at 58 in Figure 2 and mathematically defined as a cycloid. As a result of their cycloidal movement, the electrons emitted by the plate 16 impinge upon the plate 20 and cause a proportionately increased number of electrons to be emitted by the plate 20.

In like manner, the electrons emitted by the plate 20 travel in a cycloidal path 60 to the plate 22 and cause the plate 22 to emit a proportionately increased number of electrons. The plate 24 also emits a number of electrons which is proportionately greater than the number of electrons emitted by the plate 22. The electrons emitted by the plate 24 in turn travel in a cycloidal movement 62 towards the gate 28.

Because of the positioning of the gate 28 in front of the plate 24 and because of the particular bias voltage applied to the gate, the electrons emitted by the plate 24 are not able to reach the gate. This causes the electrons emitted by the plate 26 to complete the cycloidal movement 62 at a position in back of the gate 28 and to commence a second cycloidal movement 64. Since the plate 31 is also in back of the plate 26 and it is at a negative potential relative to the voltage on the plate 24, the electrons complete their cycloidal movement 64 without reaching the plate 31. After completing the cycloidal movement 64, the electrons commence a cycloidal movement 66 which causes them eventually to impinge on the collector 32.

When a sufficiently positive signal is applied to the gate 28 from the source 54, the voltage on the gate becomes positive relative to the voltage on the plate 26. This

causes the gate 28 to attract the electrons traveling in the cycloidal path 62 from the plate 26. The electrons then flow through the space between the wires 30 in the gate 28 and impinge on the plate 26. The resultant signals produced by the plate 28 are indicated by the oscilloscope 27.

The electron multiplier disclosed above has several important advantages. It accurately reproduces the pattern of a relatively weak input signal and produces an output signal which is considerably amplified with respect to the input signal. The electron multiplier produces such strong and accurate output signals even though the input signal is electrical and is not formed by a stream of particles such as from the source 10. The electron multiplier is able to amplify an electrical signal such as the signal from the source 54 by introducing the signal to a gate such as the gate 28 to control the flow of electrons to an output plate in the multiplier.

Another embodiment of the invention is shown in Figure 3. This embodiment includes plates 70, 72, 74, 76 and 78 corresponding in construction and relative positioning to the plates 16, 20, 22, 24 and 26 shown in Figure 1. A gate generally indicated at 80 is positioned in back of the plate 78 in a manner similar to that disclosed above for the gate 28 in Figure 1. The gate 78 is made from a plurality of spaced wires 82.

A plate 84 is positioned in laterally contiguous relationship to the gate 80 and in a longitudinally progressive relationship with respect to the plates 70, 72, 74 and 76. For example, when the plate 76 is positioned 0.124 inches away from the electrode 14 in a manner similar to the electrode 24 in the embodiment shown in Figure 1, the plate 84 may be positioned approximately 0.122 inches away from the electrode 14.

A plate 86 is disposed in laterally contiguous relationship to the plate 84 and in a longitudinally progressive relationship with respect to the plate. In the above example, the plate 86 may be positioned approximately 0.120 inch away from the electrode 14. A collector 88 is positioned in a substantially similar arrangement with respect to the electrode 14 and the plate 86 as the collector 32 is positioned with respect to the electrode 14 and the plate 31 in Figure 1. The collector 88 is connected to a suitable indicator such as an oscilloscope 89 to indicate the electrons impinging on the collector.

Since voltages are applied to the different plates and to the gate 80 in a manner similar to that disclosed above and shown in Figure 1, the connections to these members in Figure 3 are not shown. However, when a potential of approximately -1,200 volts is applied to the plate 76, potentials of approximately -1,000 and -800 volts may be applied to the plates 84 and 86. The gate 80 may normally be biased at a potential of approximately -1,150 volts for reasons which will be disclosed in detail hereinafter.

The plate 70 receives particles from the source 10 in a manner similar to that disclosed above and emits a proportionately increased number of electrons which travel in a cycloidal path towards the plate 72. In like manner, the plates 72, 74, and 76 receive electrons from a preceding plate and emit a proportionately increased number of electrons. The electrons emitted by the plate 76 travel in a cycloidal path 90 towards the gate 80. Since the gate is at a positive potential with respect to the potential on the plate 76, the gate attracts the electrons moving towards it from the plate. This causes the electrons to pass through the gate and to impinge on the plate 78. The movement of the electrons through the gate 80 towards the plate 78 is indicated by broken lines at 92 in Figure 3.

When a negative signal is applied to the gate 80 from a signal source 94, the voltage on the gate becomes negative with respect to the potential on the plate 76. Because of this voltage relationship, the electrons emitted by the plate 76 cannot pass through the gate for collec-

tion by the plate 78. This causes the electrons to commence a new cycloidal movement 96 after they have completed the cycloidal movement 90.

The electrons moving through the cycloidal path 96 impinge on the plate 84 and cause the plate to produce a proportionately increased number of electrons. These electrons in turn move in a cycloidal path towards the plate 86, which then emits a proportionately increased number of electrons. The electrons emitted by the plate 86 are received by the collector 88 to produce output signals on the oscilloscope 89.

The electron multipliers disclosed above are adapted to be used with different types of apparatus. For example, either of the electron multipliers previously described may be used in a mass spectrometer to indicate whether or not molecules of a particular gas or vapor are present in an unknown mixture. Figure 4 shows the electron multiplier of Figures 1 and 2 as used with a spectrometer. The mass spectrometer includes a wedge-shaped filament 100 made from a suitable material such as tungsten so as to emit electrons when heated. An electrode 102 is disposed at a relatively short distance such as $\frac{1}{4}$ millimeter away from the tip of the filament 100. The electrode 102 is provided with a vertical slot 104 the median position of which is at approximately the same horizontal level as the filament 10.

An electrode 106 is disposed in substantially parallel relationship to the electrode 102 at a relatively short distance such as 1 millimeter away from the electrode 102. The electrode 106 has a vertical slot 108 corresponding substantially in shape and position to the slot 104. A collector 110 is disposed at a relatively great distance such as 4 centimeters away from the electrode 106 and in substantially parallel relationship to the electrode.

A backing plate 112 is positioned between the electrode 106 and the collector 110 and in substantially perpendicular relationship to these members. The backing plate 112 is disposed slightly to the rear of an imaginary line extending from the tip of the filament 100, through the slots 104 and 108 to the collector 110. An electrode 114 is substantially parallel to the backing plate 112. The electrode 114 is slightly in front of the imaginary line disclosed above and a relatively short distance such as 2 millimeters in front of the backing plate 112. The electrode 114 is provided with a horizontal slot 116.

Top and bottom slats 118 made from a suitable insulating material extend between the backing plate 112 and the electrode 114 and form a compartment with these members. The bottom slat 118 has a horizontal slot 120 positioned directly below the imaginary line disclosed above. A conduit 122 communicates at one end with the slot 120 and at the other end with a receptacle 124 adapted to hold the molecules of the different gasses and vapors in an unknown mixture.

An electrode 126 is disposed in substantially parallel relationship to the electrode 114 at a relatively short distance such as 2 millimeters in front of the electrode 114. The electrode 126 is provided with a slot 128 corresponding substantially in shape and position to the slot 116 in the electrode 114. An electrode 130 corresponding to the electrode 14 shown in Figure 1 is substantially parallel to the electrode 126 at a relatively great distance such as 40 centimeters from the electrode 126. The electrode 130 is provided with a window 132 which has substantially the same positioning as the slot 128 and slightly greater dimensions than the slot.

A first plate 134 in an electron multiplier generally indicated at 136 is positioned directly in front of the window 132. Plates 138, 140, 142 and 144 are disposed in the same arrangement relative to the plate 104 as the plates 20, 22, 24 and 26 are positioned with respect to the plate 16 in Figure 1. A gate generally indicated at 146 is positioned in back of the plate 144 in a manner similar to the disposition of the gate 28 relative

to the plate 26 shown in Figure 1. A plate 148 and a collector 150 correspond in construction and positioning to the plate 31 and the collector 32 in Figure 1.

A positive voltage is applied to the electrode 102 through a resistance 152 from a suitable power supply 154. A slightly positive voltage is also applied to the collector 110 through a suitable resistance 156 from the power supply 154 to attract back to the collector electrons secondarily emitted from it upon the impingement of electrons from the filament 100. The filament 100, the backing plate 112 and the electrode 114 are connected to grounded resistances 160, 162 and 164, respectively, and the electrodes 106, 126 and 130 are directly grounded. Since the voltages applied to the plate 134, 138, 140, 142 and 144 and to the gate 146 are similar to those disclosed above for the embodiment shown in Figure 1, electrical connections to these members are not shown.

The filament 100 and the electrode 102 are respectively connected through coupling capacitances 166 and 168 to a suitable pulse forming circuit 170. Voltage pulses are also applied from the pulse forming circuit 170 through suitable coupling capacitances 172 and 174 to the backing plate 112 and the electrode 114, respectively. These pulses are applied a relatively short time after the imposition of voltage pulses on the filament 100 and the electrode 102. A connection is also made from the pulse forming circuit 170 through a suitable coupling capacitance 176 to an indicator such as an oscilloscope 178 so that the oscilloscope sweep will be initiated at the same time as the imposition of the voltage pulses on the backing plate 112 and the electrode 114. The oscilloscope 178 is connected to the plate 144 to indicate the electrons flowing to the plate.

Although the pulse forming circuit 170 is shown in block form in Figure 4, its construction and operation will be apparent to persons skilled in the art. For example, Model 902 of the Double Pulse Generator manufactured by the Berkeley Scientific Instrument Company of Richmond, California, may be used to produce a plurality of pulses separated from one another by variable periods of time. This model generator is fully described in a publication entitled "Instruction Manual, Berkeley Double Pulse Generator, Model 902," issued by the Berkeley Scientific Company in August 1950. The pulse forming circuit disclosed in co-pending application Serial No. 288,104, filed May 16, 1952, now abandoned, by Macon H. Miller and William C. Wiley may also be conveniently adapted for use.

The electrons emitted by the filament 100 are attracted to the electrode 102 because of the positive voltage on the electrode relative to the voltage on the filament. The electrons are decelerated in the region between the electrodes 102 and 106 since the electrode 106 is at substantially the same potential as the filament 100. Because of this deceleration, the electrons are not able to travel into the region between the backing plate 112 and the electrode 114 with a sufficient energy to ionize molecules of gas introduced into the region from the receptacle 124.

When negative pulses of voltage are applied to the filament 100 and the electrode 102, the electrode 102 has a negative potential applied to it with respect to the electrode 106. This causes the electrons to be accelerated in the region between the electrodes 102 and 106 and to travel into the region between the backing plate 112 and the electrode 114 with a sufficient energy to ionize molecules of gas and vapor introduced into the region from the receptacle 124. Most of the ions which are produced have a unitary positive charge.

The ions produced by the electrons traveling from the filament 100 are retained within the electron stream produced by the electrons since they have a charge opposite to that of the electron stream. The ions are retained in

the stream until a relatively large number have been produced. The electron stream is then interrupted by cutting off the pulses on the filament 100 and the electrode 102 so that the ions can be easily withdrawn from their place of retention.

The ions are withdrawn from their place of retention upon the imposition of voltage pulses on the backing plate 112 and the electrode 114. The voltage pulses may be of such magnitude as to produce an electrical field of moderate intensity between the backing plate 112 and the electrode 114 and an electrical field of considerably increased intensity between the electrodes 114 and 126. For example, pulses of approximately +400 and +380 volts may be respectively applied to the backing plate 112 and the electrode 114.

The particular voltage pulses are applied to the backing plate 112 and the electrode 114 to provide a compensation for differences in the positioning and random motion of individual ions. Differences in the positioning of individual ions result from the fact that the ions are retained in an electron stream having a finite width. Differences in the random motion of individual ions result from the thermal and other energy in the ions. As a result of this random motion some of the ions are traveling towards the backing plate 112 at the instant that they are withdrawn from their place of retention and other ions are traveling towards the electrode 112 at this instant. The compensatory actions provided by the imposition of the particular voltage pulses on the plate 112 and the electrode 114 are fully disclosed in co-pending application Serial No. 249,318, filed October 2, 1951, by William C. Wiley, now Patent 2,685,035.

When the particular voltage pulses are applied on the backing plate 112 and the electrodes 114, the ions are accelerated through the slots 116 and 128 towards the electrode 130. The ions of relatively light mass receive a greater acceleration than the ions of heavy mass and travel through the window 132 in the electrode 130 before the ions of heavy mass. This causes the ions of each mass to impinge on the plate 134 at a time dependent on their mass.

As previously disclosed, the plate 134 emits a number of electrons proportionately greater than the number of electrons which impinge on it at any instant. The plates 138, 140 and 142 also produce numbers of electrons proportionately greater than the number which impinge on them. The electrons emitted by the plate 142 are normally prevented from reaching the plate 144 since the gate 146 is provided with a negative bias relative to the voltage on the plate 142. This causes the electrons emitted by the plate 142 to impinge upon the collector 150.

At substantially the instant that ions of a particular mass are expected at the electron multiplier 136, a positive pulse of voltage is applied to the gate 146. This causes the gate 146 to attract the electrons emitted by the plate 142 so that the electrons travel through the gate and impinge on the plate 144. The resultant signal produced at the plate 144 is indicated by the oscilloscope 178. In this way, an indication is provided as to the presence or absence of ions of a particular mass in the unknown mixture.

It is to be understood that the electron multiplier shown in Figure 3 may also be used in conjunction with a spectrometer. In that situation the gate 82 would be controlled so as to reject to the plate 88 only those electrons that represent ions of the particular mass being studied.

Although this invention has been disclosed and illustrated with reference to particular applications, the principles involved are susceptible of numerous other applications which will be apparent to persons skilled in the art. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

What is claimed is:

1. In combination, a plurality of plates arranged in staggered relationship with respect to one another, each plate being disposed to receive the electrons from a preceding plate in the plurality and to produce a correspondingly increased number of electrons, means for introducing a plurality of particles to a first plate in the plurality to produce an emission of electrons from the plate corresponding to the number of particles, a gate disposed in contiguous relationship to a particular one of the plates in the plurality and disposed in lateral relationship to the preceding plate in the plurality and normally biased to pass the electrons to the contiguous plate and to prevent any of the electrons from reaching the succeeding plate in the plurality, means for introducing a voltage pulse to the gate to block the flow of electrons through the gate during the application of the voltage pulse and to provide for a movement of the electrons to the succeeding plate in the plurality, and means connected to the last plate in the plurality to provide an indication of the number of electrons impinging on the plate at any instant.

2. In combination, a plurality of plates arranged in staggered relationship with respect to one another, each plate being disposed to receive the electrons from a preceding plate and to produce a correspondingly increased number of electrons, means for introducing a plurality of particles to a first plate in the plurality to produce an emission of electrons from the plate corresponding to the number of particles, means for providing voltage pulses, a gate disposed in contiguous relationship to a particular one of the plates and normally open to pass electrons from a preceding plate to the particular plate, the gate being connected to the pulse means for blocking the flow of electrons through the gate to the contiguous plate during the application of each pulse and for providing for a movement of the electrons to the succeeding plate in the plurality, and means connected to the last plate in the plurality to provide an indication of the number of electrons received by the plate at any instant.

3. In combination, a plurality of plates arranged in progressively staggered relationship to one another, each plate being disposed to receive the electrons from a preceding plate in the plurality and to emit a correspondingly increased number of electrons, means for introducing a plurality of particles to a first plate in the plurality to produce an emission of electrons by the plate corresponding to the number of particles, a plate disposed in adjacent and regressively staggered relationship to one of the plates in the plurality, a gate disposed in contiguous relationship to the regressively staggered plate and in regressively staggered relationship to the adjacent plate in the plurality, the gate being normally closed to block the passage of electrons from a preceding plate to the regressively staggered plate, means for introducing a voltage pulse to the gate to produce a flow of electrons through the gate during the application of the voltage pulse, and means for providing an indication of the electrons flowing past the gate at any instant.

4. In combination, a plurality of plates arranged in laterally contiguous and longitudinally staggered relationship with respect to one another, each plate being disposed to receive the electrons from a preceding plate and to produce a correspondingly increased number of electrons, means for introducing a plurality of particles to a first plate in the plurality to produce an emission of electrons from the plate corresponding to the number of particles, a gate formed from a plurality of spaced wires and disposed in laterally contiguous relationship with respect to the last plate in the plurality, a plate disposed in a parallel and longitudinally contiguous relationship with respect to the gate, a circuit for biasing the gate with a voltage relative to the voltage on the regressively plate to block the flow of electrons past the gate to the plate, a circuit for applying a voltage pulse

to the gate to produce a flow of electrons through the gate to the contiguous plate during application of the voltage pulse, and means for indicating the flow of electrons through the gate at any instant.

5. In combination, a plurality of plates arranged in laterally contiguous relationship to one another and in a longitudinally progressive relationship to one another, each plate being disposed to receive the electrons from a preceding plate and to produce a correspondingly increased number of electrons, means for introducing a plurality of particles to a first plate in the plurality to produce an emission of electrons from the plate corresponding to the number of particles, a gate disposed in laterally contiguous relationship to one of the plates in the plurality to control the number of electrons flowing from the plate through the gate, a circuit for biasing the gate with a voltage relative to the voltage on the laterally contiguous plate to prevent the flow of any electrons from the plate through the gate, a circuit for imposing voltage pulses on the gate to provide for the flow of electrons from the laterally contiguous plate through the gate during the application of each voltage pulse, and means for producing signals indicative of the flow of electrons through the gate.

6. In combination, a first plurality of plates arranged in laterally contiguous and progressively staggered longitudinal relationship to one another, each plate being disposed to receive the electrons from a preceding plate and to produce a correspondingly increased number of electrons, means for introducing a plurality of particles to a first plate in the plurality to produce an emission of electrons from the plate corresponding to the number of particles, a gate disposed in laterally contiguous and regressively staggered longitudinal relationship to the last plate in the first plurality to control the number of electrons flowing from the contiguous plate through the gate, a circuit for biasing the gate with a voltage relative to the voltage on the laterally contiguous plate to pass through the gate all of the electrons flowing from the plate, a second plurality of plates disposed in laterally contiguous relationship to one another and to the gate and in progressively staggered relationship with respect to the first plurality of plates, a circuit for imposing voltage pulses on the gate to block any flow of electrons through the gate during the application of each voltage pulse and to produce a flow of electrons from the last plate in the first plurality to the first plate in the second plurality, and means associated with the last plate in the second plurality to produce signals indicative of the times at which electrons are received by the plate.

7. In combination, a plurality of plates arranged in laterally contiguous and longitudinally progressive relationship with respect to one another, each plate being disposed to receive the electrons from a preceding plate and to produce a correspondingly increased number of electrons, means for introducing a plurality of particles to a first plate in the plurality to produce an emission of electrons from the plate corresponding to the number of particles, a gate disposed in laterally contiguous relationship to a particular one of the plates in the plurality to control the electrons flowing from the contiguous plate past the gate, a circuit for biasing the plate with a voltage relative to the voltage on the contiguous plate to block the flow of electrons from the plate past the gate, a circuit for imposing pulses of voltage on the gate to provide for the flow of electrons from the laterally contiguous plate past the gate during the imposition of each voltage pulse, and means associated with the gate for producing signals indicative of the flow of electrons past the gate.

8. In combination with a mass spectrometer for accelerating ions to produce a separation of the ions on the basis of their mass, a plurality of plates disposed in laterally contiguous and longitudinally progressive relationship with respect to one another, at least one of the plates in the plurality being disposed to receive the ions

after their travel through a particular distance and to produce a corresponding number of electrons, other plates in the plurality being disposed to receive the electrons emitted by a preceding plate in the plurality and to produce a proportionately increased number of electrons, a gate disposed in laterally contiguous relationship to a particular one of the plates in the plurality to control the number of electrons flowing from the plate past the gate, a circuit for biasing the gate with a voltage relative to the voltage on the laterally contiguous plate to prevent any flow of electrons from the plate past the gate, a circuit for applying a pulse of voltage to the gate at a time corresponding to the reception by the first plate of the ions of a particular mass to provide for the movement past the gate of electrons produced as a result of the reception of the ions, and means for indicating the flow of electrons past the gate.

9. In combination with a mass spectrometer for accelerating a plurality of ions longitudinally to produce a separation of the ions on the basis of their mass, a plurality of plates disposed in laterally contiguous and longitudinally progressive relationship with respect to one another, at least one plate in the plurality being disposed to receive the ions after their travel through a particular distance and to emit a number of electrons substantially proportionate to the number of ions reaching the plate, second plates in the plurality being disposed relative to one another and to the first plate to receive the electrons emitted by a preceding plate and to emit a proportionately increased number of electrons, means for providing voltages on each of the plates dependent upon the longitudinal disposition of the plates to produce a substantially uniform electrical field, means for providing a magnetic field operative in conjunction with the electrical field to advance the electrons emitted by each plate towards a successive plate, a gate formed from a plurality of laterally spaced wires and disposed in laterally contiguous and longitudinally regressive relationship to a particular one of the second plates, means for biasing the gate with a voltage relative to the voltage on the laterally contiguous plate to prevent the flow of any electrons from the plate through the gate, means for applying pulses of voltage to the gate at substantially the instant that ions of a particular mass are expected at the first plate, the voltage pulses being of a polarity and magnitude to provide for the movement of electrons through the gate upon the application of each pulse, and means for indicating the flow of electrons through the gate.

10. In combination, a plurality of plates arranged in staggered relationship to one another, each plate being disposed to receive electrons emitted from a preceding plate in the plurality and to emit a correspondingly increased number of electrons, means for introducing a plurality of particles to the first plate in the plurality to produce an emission of electrons by the plate corresponding to the number of particles, a gate disposed adjacent to a particular plate in the plurality for passing all the electrons emitted by the particular plate upon an opening of the gate and for blocking the passage of all the electrons emitted by the particular plate upon a closure of the gate to provide for a movement of the electrons to the succeeding plate in the plurality, and a plate disposed contiguous to the gate to collect the electrons passed by the gate.

11. In combination, a mass spectrometer for producing ions and for accelerating the ions longitudinally so as to produce a separation of the ions on the basis of their mass, a first emissive plate disposed to receive the ions after their travel through a particular distance and to emit a number of electrons substantially proportionate to the number of ions reaching the plate, second emissive plates being disposed relative to one another and to the first plate to receive the electrons emitted by a preceding plate and to emit a proportionately increased number of electrons, a gate disposed in the electron stream so cre-

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ated, means for placing a charge on the gate at controlled time intervals to block the passage of all electrons reaching the gate at such times, and a plate disposed contiguous to the gate to collect those electrons that the gate passes.

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