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MASS ANALYZER HAVING SERIES ALIGNED CURVILINEAR AND RECTILINEAR ANALYZER SECTIONS

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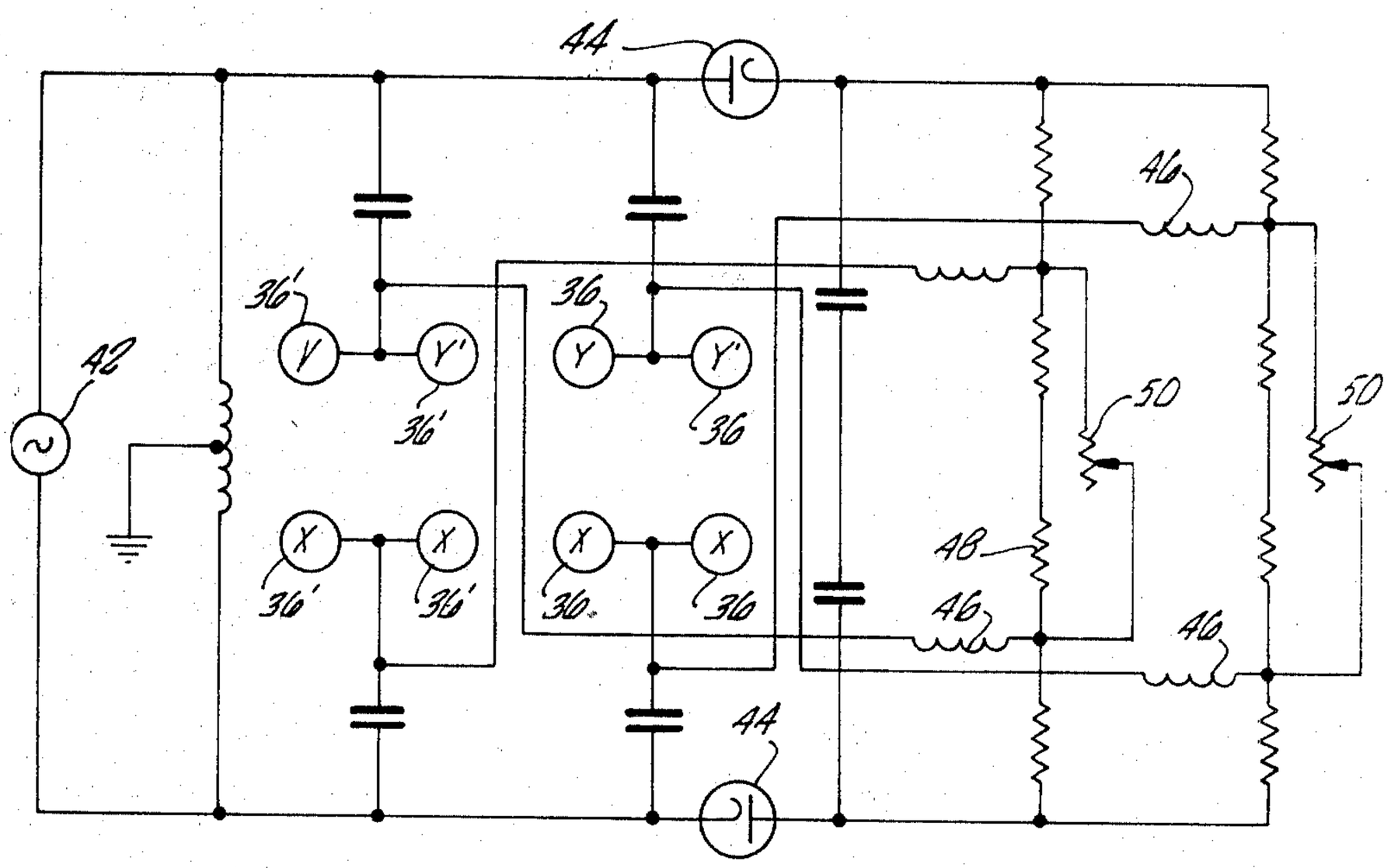

FIG. 4

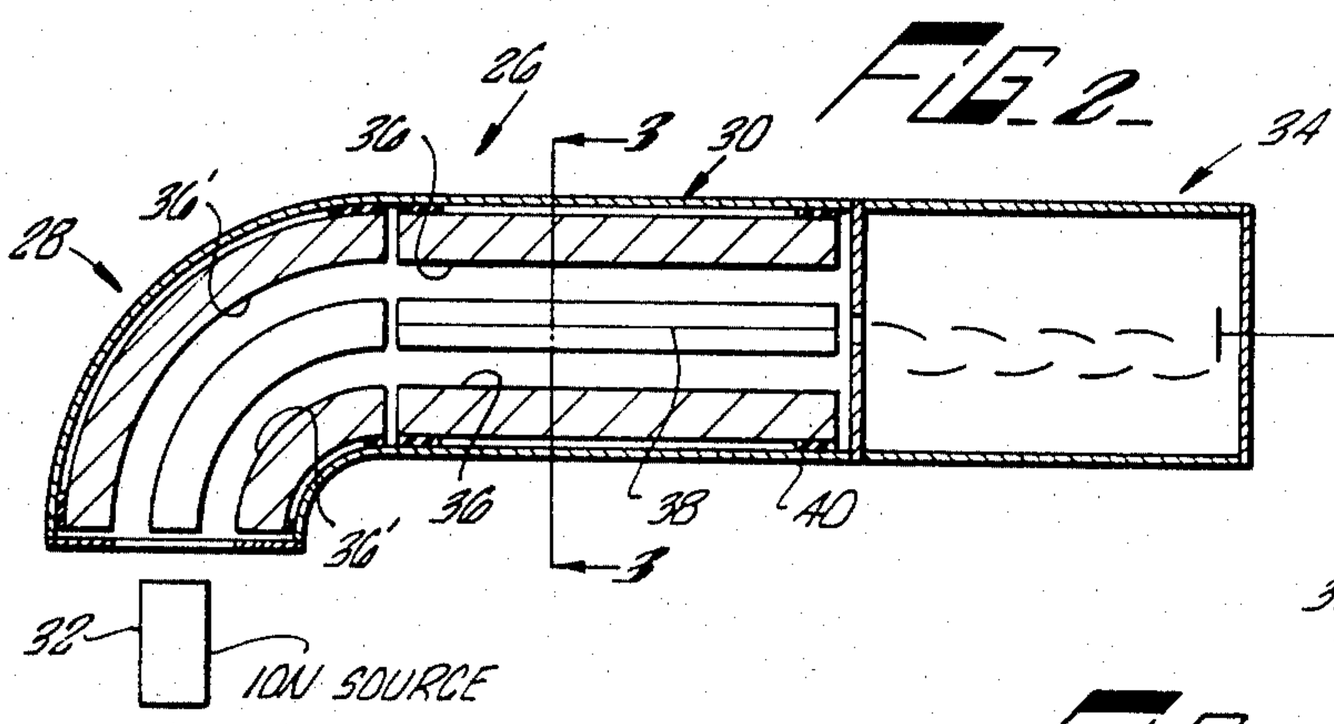

FIG. 2

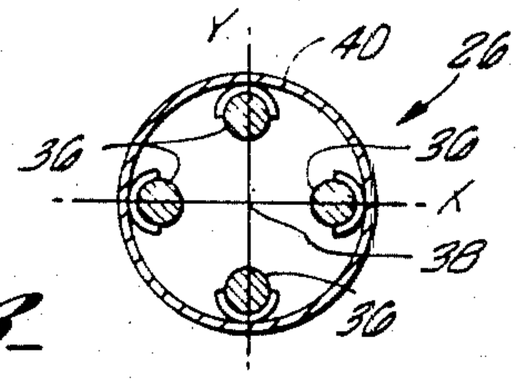

FIG. 3

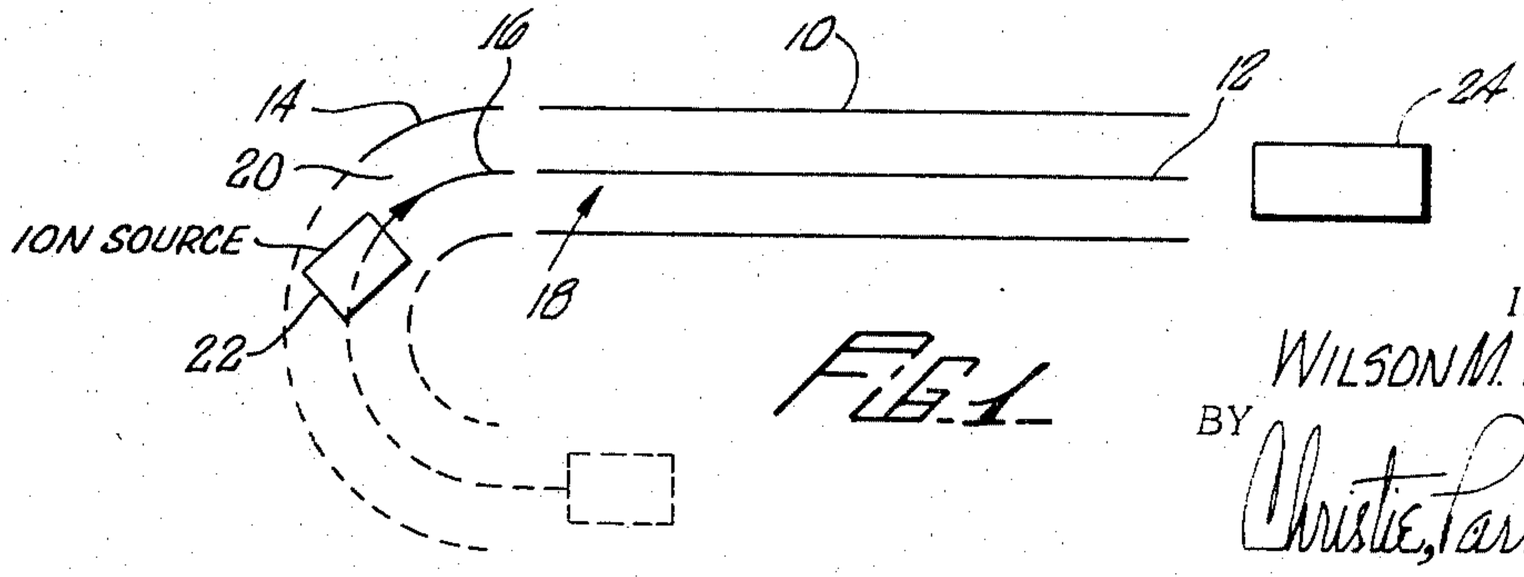

FIG. 1

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MASS ANALYZER HAVING SERIES ALIGNED CURVILINEAR AND RECTILINEAR ANALYZER SECTIONS

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11 Claims

ABSTRACT OF THE DISCLOSURE

A non-magnetic mass analyzer with a low signal to noise ratio and a wide sensitivity range. A curved analyzer section is interposed between the charged particle source and the straight section of the analyzer. By adjusting the resolving power of the curved section to a value lower than that in the straight section further improvements in operating characteristics are obtained.

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

The provision of a curved section at the exit end of a nonmagnetic mass analyzer is described in copending application, Ser No. 394,815, filed Sept. 8, 1964, now U.S. Patent 3,410,997. In a preferred embodiment this curved section is operated in the strong focussing mode with zero resolving power. The purpose of such a modification is to cause the resolved charged particle beam to traverse a curved path prior to incidence at the particle detector at the exit end of the filter and thus separate the resolved particles from photons emanating from the charged particle source. Attenuation of the number of photons reaching the detector effects a substantial reduction in the strength of the noise signal generated in the measuring circuit at the output of the analyzer.

SUMMARY OF THE INVENTION

The present invention relates to non-magnetic mass analyzers and in particular to an improved two section analyzer including a curved portion preceding a straight portion.

The analyzer includes a first section having a rectilinear axis and an entrance and an exit end. This first section comprises at least one elongated field-forming electrode and a second elongated electrode extending longitudinally of the field-forming electrode. In addition the analyzer includes a source of charged particles, a charged particle detector located at the exit end of the rectilinear section and an AC and a DC voltage source electrically connected to the field-forming electrode for creating a mass analyzing field between the electrodes. The improvement comprises a second analyzer section having curvilinear axis and an exit and an entrance end, with this second section being interposed between the entrance end of the rectlinear section and the charged particle source. The second analyzer section comprises at least one elongated field electrode and a second elongated electrode extending longitudinally of the field electrode. Means for connecting the AC and DC source to the field electrode of the second section is provided and the charged particle source is positioned relative to the entrance end of the curvilinear section so as to direct particles into the section for preliminary filtering before admission of the particles into the rectlinear section of the analyzer.

In a preferred embodiment the curvilinear section of the analyzer or filter is operated with a relatively low resolving power and the rectilinear section with a relatively high resolving power. Adjustment of the resolving power of the instrument is accomplished in one of several ways, most commonly by adjusting the ratio of the DC and AC potentials applied to the electrodes of the analyzer. By constructing a two section analyzer having a curvilinear entrance section, the number of photons from the charged particle source reaching the analyzer detector is reduced. This reduction provides a substantial improvement in the signal to the noise ratio in the output circuit of the analyzer.

With the preferred embodiment described above the invention provides the additional advantages that the deleterious effects of space charge and the buildup of insulating surfaces within the area of high resolution in the analyzer are reduced or eliminated. By operating the entrance section at a relatively low resolving power non-transmitted particles (i.e., particles not possessing the selected mass) are removed prior to entry in the portion of the analyzer in which the fine resolution is performed. This is due to the fact that ions in all but a narrow mass range are removed in the section of low resolving power. Thus the region of high space charge and heavy ion bombardment of the electrodes by charged particles occurs in the entrance section of the analyzer and thus the occurrence of these effects in the section of the analyzer having high resolving power is greatly attenuated. Absent the removal of these effects, the analyzing fields are perturbed and a diminution of the resolving power of the analyzer is experienced.

DESCRIPTION OF THE DRAWINGS

These advantages and others will be better understood by reference to the following figures in which:

FIG. 1 is a schematic illustration of a non-magnetic mass analyzer according to the present invention;

FIG. 2 is a sectional view of a quadrupole mass analyzer provided with a curved entrance section according to the invention;

FIG. 3 is a view taken along lines **3—3** of FIG. 2; and

FIG. 4 is a schematic diagram illustrating the electrical circuitry used to connect AC and DC voltages to the electrodes in both sections of the analyzer of FIGS. 2 and 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The schematic illustration of FIG. 1 is representative of the several types of non-magnetic mass analyzers commonly referred to as monopole, consisting of a cylindrical rod electrode and a right angle electrode such as is described in U.S. Patent 3,197,633, dualpole, consisting of two cylindrical rod electrodes and a flat electrode such as is described in U.S. Patent 3,418,464, and quadrupole mass analyzers, consisting of four cylindrical rod electrodes such as is described in U.S. Patent 2,950,389. Common to these various types of analyzers is a linear section **10** extending longitudinally of an axis **12**. In all of the above types at least one elongated field-forming electrodes and a second elongated electrode extend longitudinally of each other and of axis **12**. In the improvement of the present invention a curvilinear section **14**, having a curved axis **16**, is located at the entrance end **18** of the linear section **10**. At the entrance end **20** of the curvilinear section a source of charged particles **22** (normally ions) is arranged such that particles generated by the source are directed into the curvilinear section. The configuration of the curvilinear section can be of several forms, the minimum bend be-

ing on the order of approximately 20°. Thus this section can be bent through 45°, 90° and 180° as shown (FIGS. 1, 2). A charged particle detector **24** is located on axis **12** at the exit end of linear section **10**. The detector receives the particles of predetermined mass which have been passed (transmitted) by the analyzer and provides a suitable indication to the output circuitry (not shown) connected to the detector.

A specific embodiment of the invention illustrated in FIG. 1 is shown in FIGS. 2 and 3. Shown therein is a quadrupole mass filter **26** having a curvilinear entrance section **28** and a rectilinear section **30**. A charged particle source **32** directs particles into the analyzer where they are resolved and the sorted beam is then directed into a detector section **34** utilizing a secondary emission multiplier detector. The output of detector **34** is connected to a measuring circuit **37** for providing qualitative and quantitative information about the resolved charged particle beam.

As shown in FIG. 3, the analyzer comprises four cylindrical rod electrodes **36** symmetrically disposed about a central axis **38**. For reference purposes the X and Y axes intersecting at the axis **38** are superimposed on the view shown in FIG. 3. Sources of AC and DC voltage are connected by means of suitable electrical circuitry to the rod electrodes to create a multipole, mass analyzing, combined AC and DC electric field within the area bounded by the electrodes **36**. The same voltage source or other sources are likewise connected by means of suitable electrical circuitry to the rod electrodes of entrance section **28** to create a similar mass analyzing field in that portion. The analyzer is enclosed within a housing **40** which is normally evacuated by a pumping source (not shown). The section view shown in FIG. 3 is also representative of the cross section of the curvilinear section **28** of the analyzer.

One illustration of the manner in which sources of AC and DC electric potential are connected to the rod electrodes of the two sections of a quadrupole analyzer according to the present invention is shown in FIG. 4. In the schematic diagram of that figure an AC voltage source **42** is connected to the electrodes of both sections. The electrodes lying along the Y axis are indicated with the letter Y and those lying along the X axis are indicated with the letter X. The electrodes corresponding to those in the rectilinear or straight section are designated **36** while those electrodes in the curvilinear or curved section are designated by **36'**. The signal from source **42** is also connected to rectifier tubes **44** to provide rectification of the output from source **42**. The DC output of the rectifier is then connected to rod electrodes **36** and **36'** through coils **46** and impedances **48**. Impedances **48** perform a voltage dropping function such that the excitation of the electrodes of the two sections is made in accordance with the preferred embodiment referred to previously. By means of these impedances the magnitude of the DC voltage connected to the rods in the curved section of the analyzer is arranged to be lower than the magnitude of the DC voltage connected to the rods in the straight section while the AC voltage applied to both sections is the same both as to amplitude and frequency. Variable impedances **50** provide a means whereby the resolving power of the two sections of the analyzer may be varied. With this type of connection the resolving power of the curved entrance section may be maintained at a relatively low value to perform a "pre-analyzing" function such that ions in a very small mass range are transmitted from this section to the section of high resolving power defined by rod electrodes **36**.

What is claimed is:

1. In a non-magnetic mass analyzer including a first analyzer section having a rectinilear axis and an entrance and exit end located at opposite ends of the first analyzer section, respectively, the first analyzer section comprising at least one elongated field electrode and a second elongated electrode extending longitudinally of the rectilinear axis, and being disposed on opposite sides of said axis, a source of charged particles, a charged particle detector located at the exit end of the rectilinear section, and an AC and a DC voltage source electrically connected to the field electrode for creating a mass analyzing electric field between the electrodes the improvement comprising:

a second analyzer section having a curvilinear axis and an entrance and an exit end located at opposite ends of the second analyzer section, respectively, said second section being interposed between the entrance end of the rectilinear section and the charged particle source, the second analyzer section comprising at least one elongated field electrode and a second elongated electrode spaced from and extending parallel to the curvilinear axis and being disposed on opposite sides of said axis, the curvilinear axis at the exit end of said curvilinear section being aligned with the rectilinear axis of said rectilinear section, and means for connecting the AC and DC source to the field electrode of the second section, the charged particle source being positioned to direct particles into the entrance end of the curvilinear section for preliminary filtering before admission of the particles into the rectilinear section of the analyzer.

2. A mass analyzer according to claim **1** including means for adjusting the resolving power of the two sections.

3. A mass analyzer according to claim **2** wherein the resolving power of the second section has a lower value than the resolving power of the first section.

4. A mass analyzer according to claim **1** wherein the amplitude and frequency of the AC voltage connected to the electrodes of each section is the same.

5. A mass analyzer according to claim **4** wherein the magnitude of the DC voltage connected to the second section has an absolute value which is less than the magnitude of the voltage connected to the first section.

6. A mass analyzer according to claim **1** wherein the second analyzer section is of the monopole type and includes a first elongated cylindrical rod electrode and a right angle electrode, said rod electrode corresponding to said field electrode and said right angle electrode corresponding to said second electrode.

7. A mass analyzer according to claim **1** wherein the second analyzer section is of the dualpole type including two cylindrical rod electrodes and a flat electrode, disposed in a parallel relationship to a plane passing through and defined by the rod electrodes, said rod electrodes corresponding to said field electrodes and said flat electrode corresponding to said second electrode.

8. A mass analyzer according to claim **1** wherein the second analyzer section is of the quadrupole type including four cylindrical rod electrodes symmetrically disposed about an axis coinciding with the curvilinear axis of the second analyzer section, three of said rod electrodes corresponding to said field electrodes and tht fourth rod electrode corresponding to said second electrode.

9. A mass analyzer according to claim **1** wherein the curvilinear section of the analyzer is bent through a 45° angle.

10. A mass analyzer according to claim **1** wherein the curvilinear section is bent through a 90° angle.

11. A mass analyzer according to claim **1** wherein the curvilinear section is bent through a 180° angle.

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