United States Patent [19]

McIntyre

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[54] **TRANSMISSION ION CHAMBER**

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[73] Assignee: **Varian Associated,** Palo Alto, Calif.

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[52] **U.S. Cl.** **250/385,** 250/397, 250/399

[51] **Int. Cl.** **G01t 1/18**

[58] **Field of Search** 250/320, 374, 382, 384, 250/385, 389; 313/93

[56] **References Cited**

UNITED STATES PATENTS

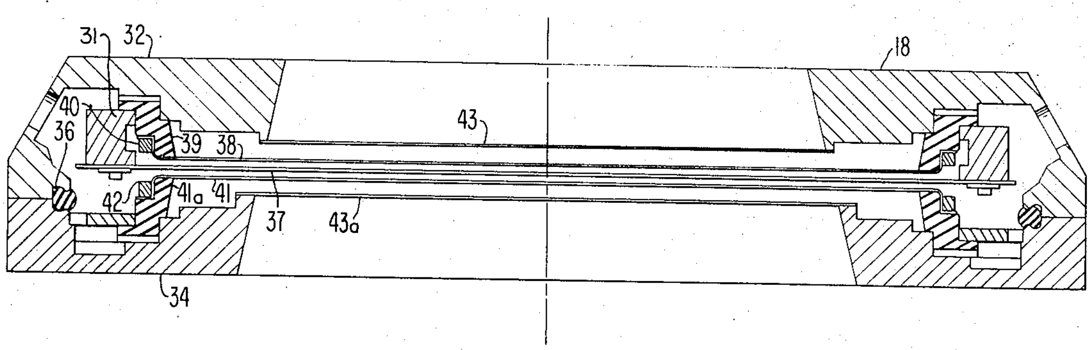
3,373,283 3/1968 Lansiart et al. 250/389

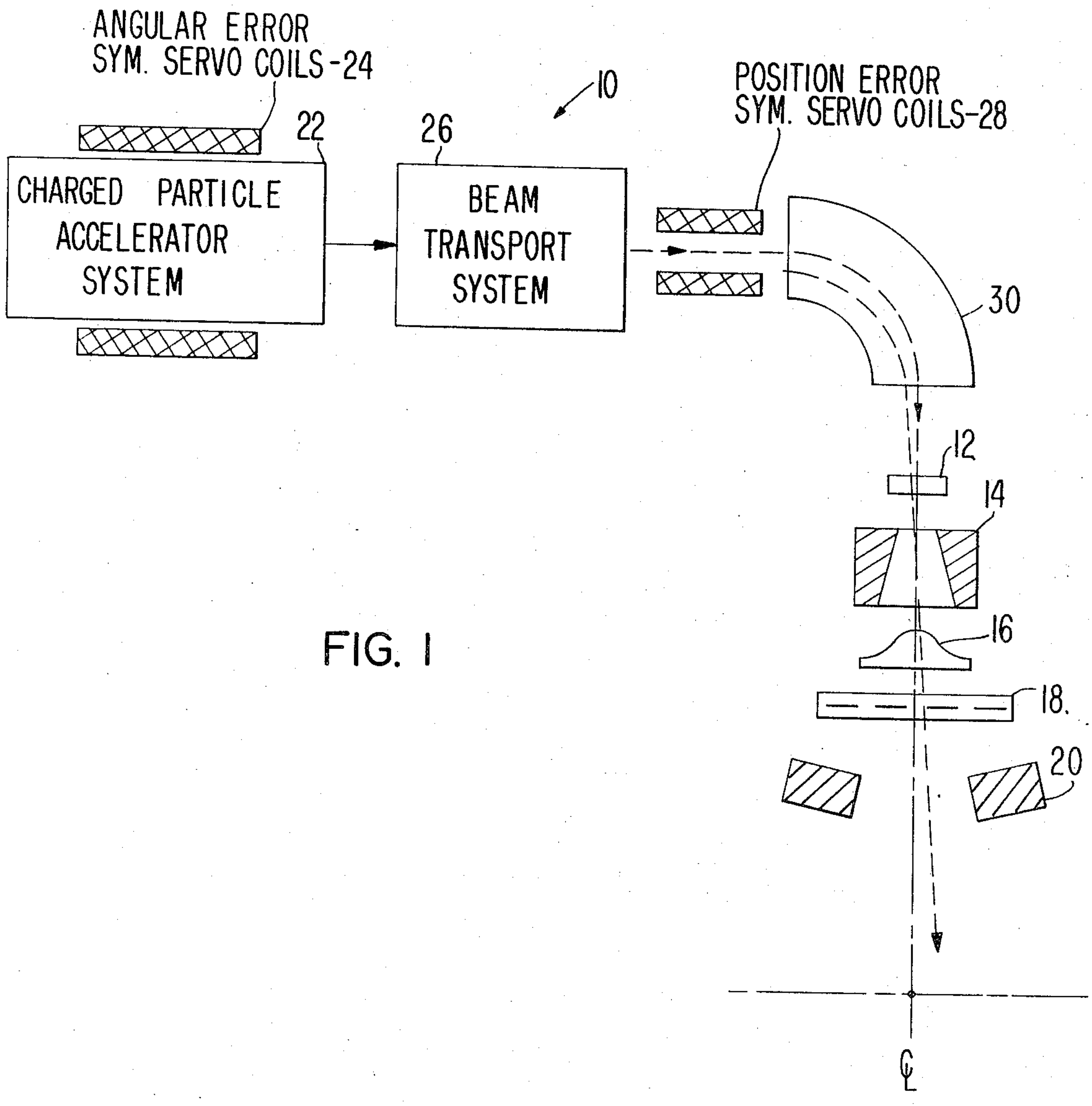
Primary Examiner—James W. Lawrence
Assistant Examiner—Davis L. Willis
Attorney, Agent, or Firm —Stanley Z. Cole and John J. Morrissey

[57] **ABSTRACT**

A linear particle accelerator having detection apparatus for detecting the presence of and correcting for beam misalignment. The linear accelerator includes a charged particle accelerator system and deflection coils for changing both the positional and angular displacement of a charged particle beam. A target is disposed in the particle beam path for emitting X-rays upon being struck by the charged particles. The photon field developed by the target takes the form of a forward-peaked lobe configuration extending from the target. An ionization chamber is disposed in the radiation field for developing electrical signals responsive to changes in the lobe field. The ionization chamber includes a housing member, and insulative sheet, such as a sheet of thin glass or mica, is supported within the housing member. A pattern of detection electrodes is formed on the insulative sheet by vacuum deposition or other similar process. A high voltage electrode comprising a sheet of conductive material is supported within the housing member in spaced parallel relationship with the detection electrodes.

29 Claims, 3 Drawing Figures




ANGULAR ERROR
SYM. SERVO COILS-24
22
26
10
POSITION ERROR
SYM. SERVO COILS-28
CHARGED PARTICLE
ACCELERATOR
SYSTEM
BEAM
TRANSPORT
SYSTEM
30
12
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16
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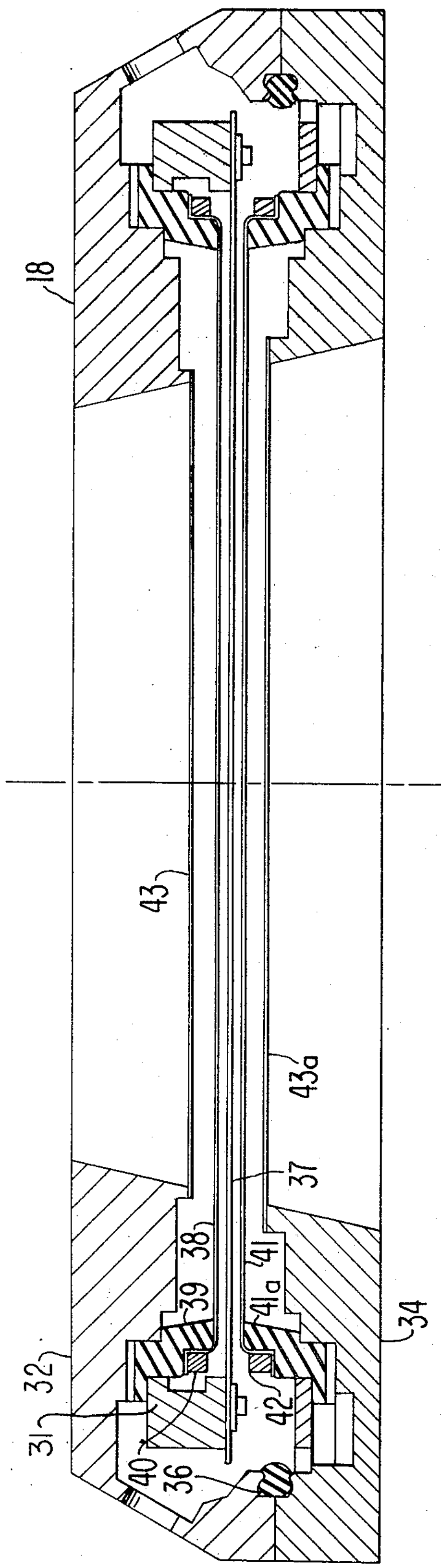
20
CL

FIG. 1


18
43
43a
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41
41a
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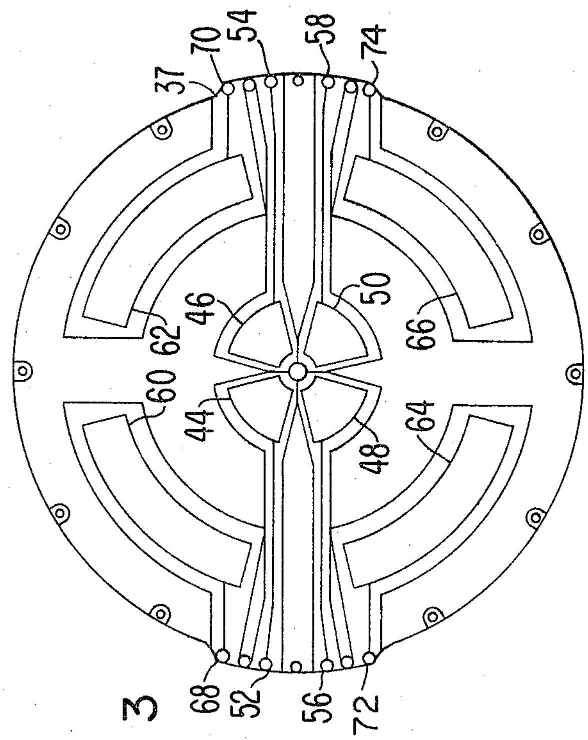
FIG. 2


37
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72

FIG. 3

TRANSMISSION ION CHAMBER

CROSS REFERENCES TO RELATED PATENTS AND PATENT APPLICATION

U.S. Pat. No. 3,322,950 to J. S. Bailey et al., entitled "Linear Accelerator Radiotherapy Device and Associated Beam Defining Structure," issued May 30, 1967 and assigned to the same assignee as the present invention.

U.S. Pat. No. 3,360,647 to R. T. Avery, entitled "Electron Accelerator with Specific Deflecting Magnet Structure and X-ray Target," issued Dec. 26, 1967 and assigned to the same assignee as the present invention.

U.S. Pat. application No. 335,634 by Craig S. Nunan and Raymond D. McIntyre entitled "Linear Particle Accelerator System Having Improved Beam Alignment and Method of Operation," filed concurrently herewith and assigned to the assignee of the present application.

BACKGROUND OF THE INVENTION

This invention pertains to the art of radiation flux measuring devices, and more particularly, to transmission ionization chambers.

Modern methods of treating cancer and other related diseases demand high intensity levels of radiation for deep X-ray therapy application. Therefore, high energy radiotherapy devices operate typically in a range of 4 to 25 million electron volts in order to obtain the desired radiation intensity distribution. In X-ray therapy it is necessary that the radiation be very precisely directed in order to obtain maximum clinical benefit from the high energy radiation.

Present day high energy X-ray systems generally comprise a charged particle accelerator which forms and projects a beam of charged particles onto a target for generating X-rays. The accelerated particles are focused and in some cases may be bent at 90° prior to being directed toward a target.

A heavy metal primary collimator is generally located at the downstream side of the target and is used to obtain the desired X-ray beam configuration. A flattening filter and an ionization chamber are normally positioned in the X-ray beam to measure dose rate and to integrate the total dose in order to obtain uniform intensity of the beam across a plane normal to the beam path. An example of such a high-energy X-ray system is disclosed in the aforementioned U.S. patent to J. S. Bailey et al.

If the beam of charged particles strikes the target at a point displaced from the center of the target, the resulting pattern of emitted X-rays is correspondingly displaced. Also, if the angle of incidence at which the particle beam strikes the target is changed, there is an angular change in the radiation pattern of X-rays leaving the target. With positional and angular misalignment of the charged particle beam striking the target, it is difficult, if not impossible, to accurately direct the emitted X-rays.

Half-plate or quadrant electrodes placed in an ionization chamber have been used to measure the distribution of radiation intensity across a charged particle radiation field. Generally, the quadrant electrodes have been symmetrically placed about a centerline of the ion chamber. The ion chamber was then positioned so that its centerline was coincident with the central axis of a radiation field. Such an array of four electrodes provided signals proportional to the integral of radiation flux passing through each quadrant and could be used to monitor symmetry of the radiation field pattern about the central axis.

The electrodes which were used in these previous ionization chambers consisted of individual metallic electrodes which were positioned within the chamber. In order to provide precise measurement with these ionization chambers, it was necessary that the individual electrodes be rigidly mounted with the required electrical isolation, which thereby severely restricted the number of collection electrodes that could be placed in the same plane within an ionization chamber. Also, mechanical support of numerous individual electrodes was very difficult. As a result, the mechanical support was often unsatisfactory, when attempts were made to place numerous very thin collector plates within a single ionization chamber.

SUMMARY OF THE INVENTION

The present invention is directed toward an ionization chamber having collection electrodes which are placed in a single plane and which are rigidly mounted so as to remain in their original positions, even if subjected to mechanical shock, thereby overcoming the above noted disadvantages, and other disadvantages of previous systems.

It has been found that by forming electrode patterns for an ionization chamber by coating a thin film of conductive material on very thin glass, or mica sheet, generally of a thickness less than 0.010 inches, it is possible to form a multiple array of collection electrodes in a single plane. The glass or mica sheet provides the necessary support and electrical isolation for the electrodes, and has been found to be relatively impervious to radiation damage. The coated electrodes may be placed on the glass, or mica plate, by the use of vacuum deposition methods, or other similar techniques. Thus, the multiple collection electrodes are maintained in a fixed relationshsip with respect to each other and with respect to an outer support housing of the ionization chamber.

In one aspect of the present invention, there is the provision of a particle accelerator system including apparatus for forming and projecting a beam of charged particles along a substantially linear path, and a target disposed in the beam path for developing a radiation field upon being struck by charged particles. An ionization chamber is positioned in the radiation field and includes a housing member and an insulative electrode support sheet supported by the housing member. The collection electrodes, each comprising a thin film of conductive material, are secured to at least a portion of one of the surfaces of the insulative sheet in superimposed parallel relationship. For example, the thin film electrodes may be coated on the insulative support sheet by vacuum depositing techniques. A high voltage electrode, comprising a sheet of conductive material, is supported by the housing member in spaced parallel relationship with respect to the film collection electrodes. An enclosure is supported by the housing member for maintaining an atmosphere of gas in the spaced region between the collection and high voltage electrodes.

In another aspect of the present invention, another collection electrode, also comprising a thin layer of conductive material, is secured to at least a portion of the other surface of the insulative sheet in superimposed parallel relationship, such as by coating a thin film of conductive material on the surface. Another high voltage electrode, comprising a sheet of conductive material, is supported by the housing member in spaced parallel relationship with the second conductive film electrode. The enclosure supported by the housing member also maintains an atmosphere of gas in the spaced region between these latter electrodes.

In another aspect of the present invention, the first collection electrodes take the form of a pattern of conductive material which is coated onto a thin glass or mica support sheet.

The objects and advantages of the invention will become apparent from the following description of a preferred embodiment of the invention as read in conjunction with the accompanying drawing in which:

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a block diagram, schematic view, illustrating in basic form a high energy X-ray system incorporating the ionization chamber of the subject invention;

FIG. 2 is a sectional view illustrating in more detail the ionization chamber shown in FIG. 1; and

FIG. 3 is a plan view illustrating in more detail the collection electrode assembly of the ionization chamber of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 generally illustrates a high energy X-ray system comprising a particle accelerator system **10** for accelerating and projecting charged particles onto a target **12**. Upon being struck by the charged particles, the target **12** emits high energy X-rays.

Downstream from the target **12** is a heavy metal primary collimator **14** which is used to obtain the desired X-ray beam configuration. Positioned downstream of the primary collimator **14**, and aligned with the opening in the collimator, is a flattening filter **16** and an ionization chamber **18**. The flattening filter **16** and the ionization chamber **18** are disposed in the radiation field to measure dose rate and to integrate the total radiation in order to generate electrical signals which are, in turn, used to maintain alignment of the particle beam. A jaw-shaped movable collimator **20** is positioned downstream from the flattening filter and ionization chamber for varying the radiation field size.

More particularly, the particle accelerator system **10** includes a charged particle accelerator **22** for forming charged particles, accelerating the particles, and focusing the particles into a beam. Angular error symmetry servomechanism coils **24**, which are associated with the particle accelerator **22**, serve the function of changing the angle of incidence at which the beam of charged particles strike the target **12**.

The beam of particles generated by the accelerator **22** passes through a beam transport system **26** and through position error symmetry servomechanism coils **28**. The beam transport system **26** includes focusing coils and various slits for shaping the particle beam. The position error servomechanism coils **28** serve the function of changing the location on the target **12** at which the particle beam strikes the target.

Disposed between the position servomechanism coils **28** and the target **12** is a beam bending magnet **30** which serves to bend the beam of charged particles through a 90° angle. Reference is made to the aforementioned United States Patent to R. T. Avery for an example of an electron accelerator which utilizes 90° beam bending techniques.

FIG. 2 illustrates in more detail the ionization chamber **18**. More particularly, the ionization chamber comprises a pair of mating ring members **32, 34,** which when engaged with each other form an outer support housing. A resilient ring seal **36** is positioned in a slot formed at the abutting surfaces of the ring members to thereby provide an air tight seal between ring members.

An electrode support plate **37** is mounted on and is electrically connected via guard ring structure **31** to the upper ring member **32**, as viewed in FIG. **2**. The electrode support plate **37** comprises an insulative sheet, such as a thin mica or glass plate, on which a pattern of thin-film conductive material is vacuum deposited. This thin-film conductive layer provides the collection electrodes. Thus, any desired electrode pattern may be deposited onto the insulative sheet. The thin-film collection electrodes may be coated on either one side of the support plate **37** or on both sides of this plate. By placing different patterns of collection electrodes on both sides of the support plate, it is possible to simultaneously measure different combinations of radiation field intensities. These collection electrodes are electrically insulated from the upper ring member **32**.

A high voltage electrode **38**, which takes the form of aluminum foil, is stretched across an insulator ring **39** and is retained in position on the insulator ring **39** by a retainer ring **40**. The insulator ring **39** is mounted on and supported by the upper housing member **32** in a manner so that the aluminum foil electrode **38** is maintained in spaced parallel relationship with the electrode support plate **37**.

A high voltage electrode **41**, which takes the form of aluminum foil, is stretched across an insulator ring **41*a*** and is retained in position on the insulator ring **41*a*** by a retainer ring **42**. The insulator ring **41*a*** is mounted on and supported by the lower housing member **34** in a manner so that the aluminum foil electrode **41** is maintained in spaced parallel relationship with the electrode support plate **37**.

A pair of aluminum cover plates **43, 43*a***, are secured across the openings of the upper and lower ring members **32, 34** to protect the high voltage electrodes and the electrode assembly, and provide a sealed enclosure for the gas in the ion chamber.

FIG. **3** illustrates an arrangement of electrodes on the electrode support plate **37** positioned within the ionization chamber **18**. The electrodes perform the function of measuring radiation intensities in the radiation field.

The electrodes take the form of four planar electrodes **44, 46, 48, 50,** each of which is situated in one of the quadrants of the circular disc-shaped ionization chamber **18**. The electrodes **44, 46, 48, 50,** which comprise the inner set of electrodes, are each slightly spaced from a central axis of the disc-shaped chamber **18** and each extends outwardly for a distance of approximately one-fourth of the radial distance of the ionization chamber. As illustrated in FIG. **1**, the inner quadrant of electrodes are positioned under the flattening filter **16** at locations directly beneath the steepest slope of the flattening filter. By so positioning these electrodes, tilt of the lobe pattern in this region of the flattening filter is compensated for by increased absorption in the flattening filter. Thus, these electrodes are only responsive to changes in the position of the radiation lobe. Each of the inner electrodes **44, 46, 48, 50** is connected to a corresponding one of four output terminals **52, 54, 56, 58.**

The ionization chamber **18** also includes an outer set of four planar electrodes **60, 62, 64, 66,** each of which is positioned in the same quadrant as one of the inner electrodes **44, 46, 48, 50.** The electrodes of the outer set are of an arcuate configuration with the center of curvature of the curved portions thereof being the central axis of the disc-shaped chamber **18.** The electrodes of the outer set of electrodes are radially spaced from the central axis of the ionization chamber at positions more remote than the inner electrodes. The outer electrodes are disposed at locations to detect the intensity of the radiation lobe pattern at the outer edges, or shoulders, of the lobe to thereby measure the tilt of the lobe. Each of the outer electrodes **60, 62, 64, 66** is electrically connected to a corresponding one of four output terminals **68, 70, 72, 74.**

The planar electrodes **44, 46, 48, 50, 60, 62, 64, 66** are all placed in a single plane in the ionization chamber **18** and are supported by an insulative plate **37** which is positioned in a disc-shaped housing member. The high voltage electrode **38** is maintained in spaced parallel relationship with the collection electrodes, and the chamber **18** is filled with an ionizable gas. Thus, each of the detector electrodes collects ion current proportional to the radiation field intensity averaged over the electrode area.

While FIG. **3** illustrates only a pattern of thin-film collection electrodes placed on one side of the electrode support plate **37,** it is to be understood that a pattern of thin-film collection electrodes may similarly be placed on the opposite side of the electrode support plate. By using two different patterns of collection electrodes on opposite sides of the support plate, it is possible to simultaneously measure radiation levels along different patterns of locations within the radiation field.

As is now apparent, the subject invention provides a technique for rigidly supporting numerous collection electrodes in a fixed plane and in any desired pattern of electrodes. Also, the electrodes are maintained at a constant distance from the high voltage electrode.

Although the invention has been shown in connection with a preferred embodiment, it will be readily apparent to those skilled in the art that various changes in form and arrangements of parts may be made to suit requirements without departing from the spirit and scope of the invention as defined by the appended claims.

Having thus described my invention, I claim:

1. In a particle accelerator system including means for forming and projecting a beam of charged particles along a substantially linear path, and target means disposed in said beam path for developing a radiation field upon being struck by said charged particles: ionization chamber means disposed in said radiation field and including a housing member; an insulative support sheet mounted within said housing member, said insulative support sheet having first and second oppositely facing surfaces; first electrode means comprising a film of conductive material secured to at least a portion of one of said surfaces of said insulative support sheet and positioned in superimposed parallel relationship with respect to said one of said surfaces; second electrode means spaced apart from said first electrode means, said second electrode means comprising a sheet of conductive material supported by said housing member in spaced parallel relationship with respect to said conductive film of said first electrode means; third electrode means comprising a film of conductive material secured to at least a portion of the other of said surfaces of said insulative support sheet and positioned in superimposed parallel relationship with respect to said other of said surfaces; fourth electrode means spaced apart from said third electrode means, said fourth electrode means comprising a sheet of conductive material supported by said housing member in spaced parallel relationship with respect to said conductive film of said third electrode means; and enclosure means supported by said housing member for maintaining an ionizable gas in the spaced region between said electrode means.

2. An apparatus as disclosed in claim **1** wherein said first electrode means takes the form of plural strips of conductive material secured to portions of said one surface of said insulative sheet and positioned in superimposed parallel relationship with respect to said surface.

3. An apparatus as disclosed in claim **1** wherein said film of conductive material takes the form of a coating of conductive material bonded to said one surface of said insulative support sheet.

4. An apparatus as disclosed in claim **1** wherein said film of conductive material takes the form of a vacuum deposited coating of conductive material bonded to said one surface of said insulative support sheet.

5. An apparatus as disclosed in claim **1** wherein said insulative support sheet comprises of a mica sheet and said film of conductive material takes the form of a coating of conductive material bonded to one of the surfaces of said mica sheet.

6. An apparatus as disclosed in claim **1** wherein said insulative support sheet comprises a glass sheet and said film of conductive material takes the form of a coating of conductive material bonded to one of the surfaces of said glass sheet.

7. An apparatus as disclosed in claim **1** wherein said second electrode means takes the form of a conductive foil.

8. An apparatus as disclosed in claim **1** wherein both said films of conductive material take the form of a coating of conductive material bonded to the surfaces of said insulative support sheet.

9. A radiation apparatus comprising a charged particle accelerator for forming and projecting a beam of charged particles along a path; target means disposed in said path, said target means being capable of generating a radiation field upon being struck by said beam of charged particles; ionization chamber means disposed in said radiation field, said ionization chamber means comprising a sealed enclosure for containing an ionizable gas therewithin; a radiation resistant electrically insulating support structure mounted within said enclosure; a plurality of coating electrodes comprising electrically conductive material coated on said support structure in discontiguous relation to each other; and an electrode comprising an electrically conductive surface disposed in said enclosure spaced apart from said coating electrodes; said coating electrodes being arranged in a pattern on said support structure such that the configuration of said radiation field in said ionization chamber means is determinative of the presence of an ionization current between said spaced apart electrode and any one of said coating electrodes.

10. The apparatus of claim **9** further comprising electric circuitry responsive to the presence of an ionization current between said spaced apart electrode and any one of said coating electrodes, and servomechanism means responsive to said electric circuitry for correcting said beam path whereby a constant configuration of said radiation field can be maintained.

11. The apparatus of claim **9** wherein said support structure comprises a solid dielectric material.

12. The apparatus of claim **9** wherein said support structure comprises a mica sheet.

13. The apparatus of claim **9** wherein said support structure comprises a glass sheet.

14. The apparatus of claim **9** wherein said coating electrodes are bonded to said support structure by a vacuum deposition bond.

15. The apparatus of claim **9** wherein said coating electrodes are substantially coplanar with each other and said spaced apart electrode is disposed parallel to said coplanar electrodes.

16. The apparatus of claim **9** wherein said spaced apart electrode comprises a metal foil.

17. The apparatus of claim **16** wherein said metal is aluminum.

18. The apparatus of claim **9** wherein said support structure comprises a dielectric plate having two oppositely facing parallel sides, said plurality of coating electrodes being bonded to one side of said plate and said spaced apart electrode being adjacent said one side of said plate; said apparatus further comprising another plurality of coating electrodes, said other coating electrodes being bonded to the other side of said plate, and another electrode comprising an electrically conductive surface disposed in said enclosure, said other electrode being adjacent said other side of said dielectric plate and spaced apart from said other coating electrodes.

19. An ionization chamber comprising a sealed enclosure for containing an ionizable gas therewithin, a radiation resistant electrically insulating support structure mounted within said enclosure, a plurality of coating electrodes comprising electrically conductive material coated on said support structure in discontiguous relation to each other, and an electrode comprising an electrically conductive surface disposed in said enclosure spaced apart from said coating electrodes.

20. The ionization chamber of claim **19** further comprising electrically conductive path means along said support structure from each coating electrode to a unique terminal corresponding to said coating electrode, each of said terminals being capable of coupling an electrical signal from one of said coating electrodes to means responsive to said signal whenever an ionization current is present between said spaced apart electrode and said coating electrode.

21. The ionization chamber of claim **20** wherein said terminals are located adjacent the perimeter of said dielectric support structure.

22. The ionization chamber of claim **19** wherein said support structure comprises a solid dielectric material.

23. The ionization chamber of claim **19** wherein said support structure comprises a mica sheet.

24. The ionization chamber of claim **19** wherein said support structure comprises a glass sheet.

25. The ionization chamber of claim **19** wherein said coating electrodes are bonded to said support structure by a vacuum deposition bond.

26. The ionization chamber of claim **19** wherein said coating electrodes are substantially coplanar with each other and said spaced apart electrode is disposed parallel to said coplanar electrodes.

27. The ionization chamber of claim **19** wherein said spaced apart electrode comprises a metal foil.

28. The ionization chamber of claim **27** wherein said metal is aluminum.

29. The ionization chamber of claim **19** wherein said support structure comprises a dielectric plate having two oppositely facing parallel sides, said plurality of coating electrodes being bonded to one side of said dielectric plate and said spaced apart electrode being adjacent said one side of said dielectric plate; said ionization chamber further comprising another plurality of coating electrodes, said other coating electrodes being bonded to the other side of said dielectric plate, and another electrode comprising an electrically conductive surface disposed in said enclosure, said other electrode being adjacent said other side of said dielectric plate and spaced apart from said other coating electrodes.

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