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ELECTRON BEAM APPARATUS

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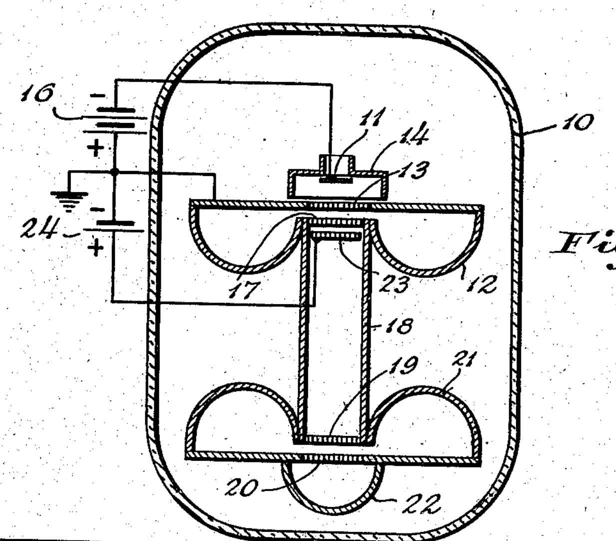

Fig. 1.

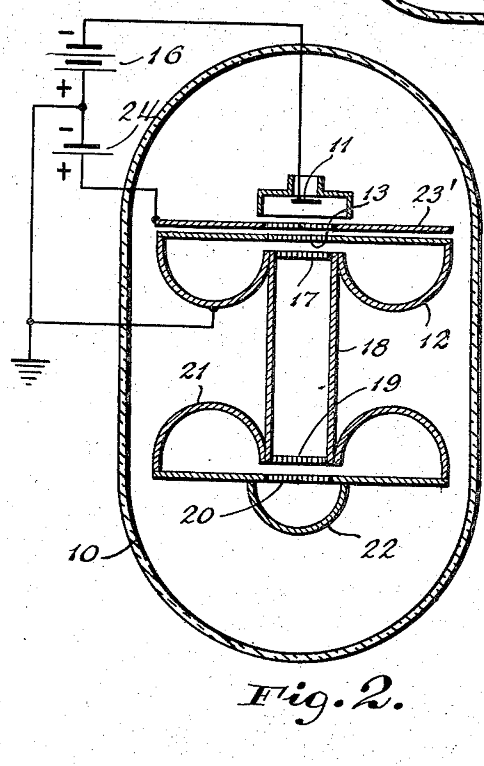

Fig. 2.

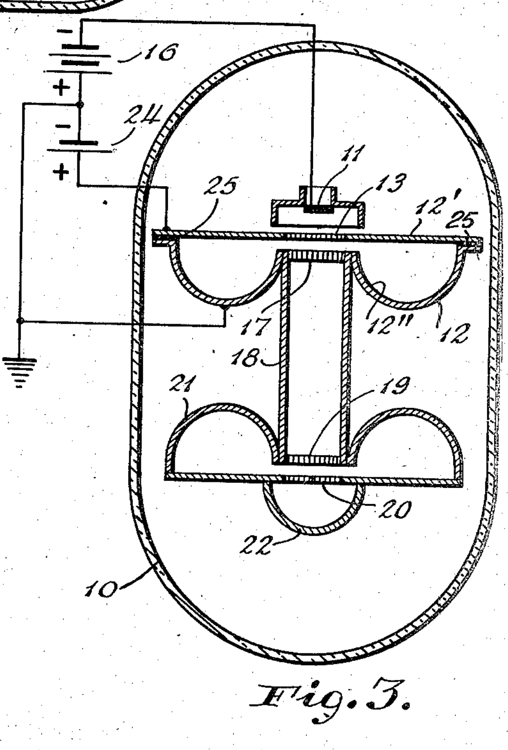

Fig. 3.

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ELECTRON BEAM APPARATUS

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13 Claims. (Cl. 315—5)

1

The present invention is related to the art including electron beam devices and especially to velocity modulation electron discharge devices of the type disclosed in Varian Patent No. 2,242,275, issued May 20, 1941. In such devices, and in many other types of electron discharge devices utilizing relatively long electron streams, difficulty is often experienced in attaining satisfactory operation due to the dispersion of the electron beam caused by the mutual repelling action of the electrons comprising the beam.

In the past, attempts to overcome this disadvantage were made by relying on the ionizing of a residual and extremely low-pressure gas within the evacuated envelope of the device, whereby the positive ions serve to neutralize the dispersing effect of the electron stream. This action has been found to be effective with respect to relatively low velocity electron beams and ordinary degrees of evacuation. However, for higher power and longer life tubes, it is necessary to use better evacuation and higher velocity beams. Under these conditions the dispersion of the beam is no longer prevented.

Investigation has shown that the failure to maintain the beam definition is caused by the "leakage" of the cathode electrostatic field beyond the usual accelerating grid, through the grid openings. Plotting of the electrostatic field shows that near the grid, and on the side thereof remote from the cathode, an electric field gradient exists which attracts positive ions toward the cathode. These ions therefore move through the grid toward the cathode, leaving the electron beam unneutralized at this point. The unneutralized electron beam forms a resultant negative space charge region which draws positive ions from regions farther from the grid, thus further extending the negative space charge and extending the region in which this drainage effect is evidenced. In this way, the positive ions are prevented from maintaining the beam sharply defined.

According to the present invention, this effect may be eliminated by interposing an ion suppressor or shielding grid immediately beyond the first anode or accelerating grid; that is, on the side of such accelerating grid remote from the cathode. By impressing a positive or zero potential on this ion-suppressor grid relative to the anode or accelerating grid, no positive ion formed in the beam beyond this ion-suppressor grid can reach the ion-suppressor electrode and, accordingly, the drainage of positive ions from the beam in this region is prevented.

2

Accordingly, it is an object of the present invention to provide improved electron discharge tube apparatus of the electron beam type in which the dispersion of the electron beam is greatly reduced.

It is another object of the present invention to provide improved electron discharge tube apparatus in which the draining of positive ions from the region occupied by the electron stream is substantially prevented.

A further object of the present invention is to provide improved electron beam devices in which the dispersion of the electron beam is greatly minimized by preventing the draining of positive ions from the region occupied by the beam, by means of an ion suppressor grid placed near the electron beam-accelerating grid and biased positively with respect to it.

A further object of the present invention is to provide an improved electron beam device in which the dispersion of the electron beam is greatly minimized by preventing the draining of positive ions from the region occupied by the beam, by means of splitting a resonator positioned along the beam path into two sections statically insulated from each other and having one section function as the accelerating grid and as the ion-suppressor electrode while being biased positively with respect to the other section.

Other objects and advantages of the present invention will become apparent from the following specification and drawings, in which:

Fig. 1 shows a schematic circuit diagram of one form of the present invention;

Fig. 2 shows a schematic representation of a second form of the present invention; and

Fig. 3 shows a schematic representation of still another form of the present invention.

Referring to Fig. 1, the present invention is disclosed as applied to a velocity modulation device of the type shown in the above-mentioned patent. However, it is to be understood that the present invention is equally applicable to any type of electron beam device, but is most particularly applicable to devices wherein an electron beam flows through a field-free space, since it is in such field-free spaces that the dispersion tendency of the beam can be most readily corrected.

In Fig. 1 there is shown an electron beam velocity modulation device having a cathode schematically shown at 11, from which electrons are projected through a hollow cavity resonator 12 through the entrance or accelerating grid 13 thereof, by means of accelerating battery 16. A focusing shield 14, as is well known in the art, may be placed around cathode 11 to direct electrons toward grid 13 from cathode 11. Resonator 12 is also provided with an exit grid 17 through which the electrons leave the space confined by the resonator 12 and enter the field-free drift space provided by conducting drift tube 18. The electrons may thereafter pass successively through the entrance and exit grids 19 and 20 of a second resonator 21 and are thereafter collected by a suitable collector 22. If desired, the vacuum envelope indicated at 10 may include resonators 12 and 21 and drift tube 18 as portions of the evacuated enclosure.

As described more in detail in the abovementioned Patent No. 2,242,275, if resonator 12 contains a high frequency oscillating electromagnetic field, the electron stream passing therethrough will have the electrons thereof periodically and recurrently varied in velocity. These variable velocity or velocity-modulated electrons, upon passing within drift tube 18, become grouped by the action of the faster electrons in overtaking the slower electrons. The grouped electron stream passing through the grids 19 and 20 of resonator 21 gives up energy at this high frequency to the field within the resonator 21 from which this energy may be taken by suitable means (not shown) for use as desired. By suitable connections, which are not material to the present invention and are not shown, the device just described may act as an amplifier, oscillator, detector, modulator, frequency multiplier, or in many other capacities. The velocity-modulated stream may be used in any desired way, so far as the present invention is concerned.

In devices of this type the path of the electron stream is relatively long, and the stream tends to become dispersed or defocused due to the mutual repulsion of the negatively charged electrons comprising the stream. This action is frequently evident within drift tubes, such as 18, which define field-free spaces where there are substantially no outside potentials or fields acting on the stream. As a result, the electrons of the stream become quite dispersed before reaching grid 19, and the efficiency and rating or power capacity of the device are greatly decreased. This dispersing action may be overcome by the introduction or retention of a slight amount of gas or vapor within the evacuated envelope 10 of the device, so that the passage of electrons will ionize the material within the envelope 10. As is well known, such ionization creates positively charged ions and negatively charged electrons. The electrons produced by ionization, having relatively large velocities with random directions, soon leave the region occupied by the electron beam. The positive ions, however, having relatively large mass and slow velocity, remain in this region and serve to neutralize the negative charges of the beam, so that, as the electrons flow along the beam, their mutual repulsion is neutralized and substantially no dispersion or defocusing occurs.

This phenomena has been utilized in the prior art but has been found to be not fully satisfactory, in that dispersion of the electron beam is not completely overcome, especially where high velocity electron beams are used. I have found that there is a weak electrostatic field near grid 13 on the side opposite cathode 11 which attracts positive ions toward the cathode 11. This field is produced by the arrangement of the electric field lines near the grid openings of grid 13 and may be considered to "reach in" through grid 13. This field draws positive ions toward it, leaving a nearby region of unneutralized electron beam which is negatively charged, due to the preponderance of negative charges in the beam. Therefore, positive ions are attracted from the next adjacent region, which then becomes negative and in turn draws ions from the next region. This action continues and, in this way, the draining of positive ions from the region of the beam is extended well into drift tube 18. In order to reduce this effect, and according to the present invention, there is provided a further ion-suppressor or shielding grid 23 within the drift tube 18, close to grid 17 but insulated therefrom and maintained at zero or a slightly positive potential with respect thereto, as by means of battery 24. In other words, the potential gradient between suppressor grid 23 and portions of the drift tube 18 extending between the grid 23 and the second resonator 21 has its more positive portion at the grid 23; consequently, it can be said: with respect to the portions of the drift tube 18 extending between suppressor grid 23 and the second resonator 21, the potential gradient has its more positive portion closer to the cathode 11. Since shielding grid 23 is now at a slightly positive potential with respect to the effective potential of the beam, there will be no tendency for positive ions in drift tube 18 to be attracted to the cathode 11 or grid 13, because of the shielding effect of grid 23. In this way, the major cause of the draining of positive ions from the electron beam is eliminated and the positive ions are left within the beam to neutralize the dispersion effect of the beam, so that the beam has little or no tendency to spread.

Instead of placing the shielding grid 23 within the drift tube 18, it may also be placed between resonator grid 13 and cathode 11, in the manner shown at 23′ in Fig. 2. The battery 24 is connected between the suppressor electrode 23′ and the resonator 12; and the latter element in turn is electrically connected to the drift tube 18 so that the potential gradient between electrode 23′ and drift tube 18, with respect to drift tube 18, has its more positive portion closer to the cathode 11. This also has the effect of shielding the positive ions from the influence of the cathode 11, and is even more effective than the arrangement shown in Fig. 1.

As another modification, the shielding electrode may be placed at the far end of drift tube 18, in addition to or substitution for electrode 23 shown in Fig. 1, or grid 23′ of Fig. 2, to prevent ion draining at that end.

A further modification of the present invention is shown in Fig. 3, in which, in place of utilizing a separate shielding grid, the resonator 12 is split into two sections 12′ and 12″, relatively insulated from one another with respect to static potentials by any suitable insulation 25. In this instance, section 12′ of resonator 12 with its grid 13 assumes the function of the shielding grids 23, 23′ of the prior figures. Thus, battery 24 maintains section 12′ slightly positive with respect to section 12″. It will be understood that the potential gradient between the sections 12′ and 12″, with respect to section 12″, thereby has its more positive portion closer to the cathode 11. In this way, there is no tendency for the positive ions of the electron beam within drift tube 18 to be drained out by the action of cathode 11.

If desired, portion 12″ may be insulated from drift tube 18 and portion 12', and maintained positive with respect thereto, whereby beam dispersion is prevented in this way also.

Although the present invention has been disclosed with respect to a velocity modulation device, it is to be understood that the invention may be equally applied to any other type of electron beam tubes using elongated electron beams, of the velocity modulation type or other type, and need not be restricted to the velocity-modulation type, or even to the double-resonator velocity-modulation type.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. High frequency velocity modulation electron discharge tube apparatus, comprising means including a cathode for producing an electron beam, a cavity resonator positioned along the path of said beam and adapted to contain a confined electromagnetic field for interaction with said beam, drift-space means beyond said resonator defining a field-free drift space surrounding the path of said beam beyond said resonator, said beam path being evacuated except for residual gas, and positive-ion-repelling means along said path for producing a potential gradient having its more positive portion closer to said cathode, thereby shielding said drift space from said cathode to prevent draining of the positive ions of said gas from said drift space whereby dispersion of said electron beam is minimized.

2. High frequency velocity modulation electron discharge tube apparatus as in claim 1, wherein said last-named means comprises a shielding electrode, and means coupled to said electrode for applying a potential to said electrode positive with respect to said drift-space-defining means.

3. High frequency velocity modulation electron discharge tube apparatus as in claim 1, wherein said last-named means comprises a shielding electrode positioned between said beam-producing means and said resonator.

4. High frequency velocity modulation electron discharge tube apparatus as in claim 1, wherein said resonator comprises two insulated portions and wherein said shielding means comprises means for maintaining one of said portions at a different static potential from the other of said portions.

5. High frequency velocity modulation electron discharge tube apparatus as in claim 1, wherein said resonator comprises two insulated portions and wherein said shielding means comprises means for maintaining the one of said portions adjacent said drift space at a positive potential with respect to the other of said portions.

6. High frequency velocity modulation electron discharge tube apparatus comprising means including a cathode for producing an electron beam, a cavity resonator positioned along the path of said beam and adapted to contain a confined electromagnetic field for interaction with said beam, drift-space means beyond said resonator defining a field-free drift space surrounding the path of said beam beyond said resonator, said beam path being evacuated except for residual gas, and means along said path for shielding said drift space from said cathode to prevent draining of

the positive ions of said gas from said drift space, whereby dispersion of said electron beam is minimized, said last-named means comprising a shielding electrode within said drift space, and means connected to said electrode for positively charging said electrode with respect to said drift-space-defining means.

7. High frequency velocity modulation electron discharge tube apparatus comprising means including a cathode for producing an electron beam, a cavity resonator positioned along the path of said beam and adapted to contain a confined electromagnetic field for interaction with said beam, drift-space means beyond said resonator defining a field-free drift space surrounding the path of said beam beyond said resonator, said beam path being evacuated except for residual gas, and means along said path for shielding said drift space from said cathode to prevent draining of the positive ions of said gas from said drift space, whereby dispersion of said electron beam is minimized, said last-named means comprising a shielding electrode within said drift space and adjacent said resonator, and means connected to said electrode for applying a positive potential to said electrode with respect to said drift-space-defining means.

8. High frequency electron beam apparatus comprising means for producing an electron beam, conductive means along the path of said beam and defining a field-free drift-space enclosing said path, said beam path being evacuated except for residual gas, and a shielding electrode positioned within said drift space and having a positive potential with respect to said conductive means, whereby the draining of the positive ions of said gas from said drift space and dispersion of said beam is minimized.

9. High frequency electron beam apparatus comprising conductive means defining a field-free drift space, means aligned with said first means for projecting a beam of electrons through said drift space, a shielding electrode located within said drift space near the point of entrance of said electrons, and means coupled to said electrode for maintaining said electrode at a positive potential with respect to said conductive means, whereby the draining of positive ions from said drift space and dispersion of said beam is minimized.

10. High frequency electron beam apparatus compirsing conductive means defining a field-free drift space, means aligned with said first means for projecting an electron beam through said drift space, and means comprising a shielding electrode located within said drift space for preventing draining of positive ions from said drift space, whereby dispersion of said beam is minimized.

11. High frequency electron beam apparatus comprising means for producing an electron stream, a cavity resonator positioned along the path of said stream for interaction therewith, an envelope surrounding the path of said stream and evacuated except for residual gas, conductive means defining a field-free drift space surrounding said stream path, an electron-permeable electrode mounted across the end of said drift-space-defining means opposite said cathode, and positive-ion-repelling means along said path for producing a potential gradient having its more positive portion closer to said cathode, thereby preventing passage of positive ions from said drift space toward said cathode.

12. High frequency electron beam apparatus as in claim 11, wherein said last-named means com-

prises an electron-permeable suppressor electrode between said cathode and said first-named electrode, and means connected to said suppressor electrode for maintaining said suppressor electrode at a positive potential relative to said first-named electrode.

13. High frequeny electron beam apparatus comprising means for producing an electron stream, a cavity resonator positioned along the path of said stream for interaction therewith, an envelope surrounding the path of said stream and evacuated except for residual gas, conductive means defining a field-free drift space surrounding said stream path, an electron-permeable electrode mounted across the end of said drift-space-defining means opposite said cathode, and means along said path for preventing passage of positive ions from said drift space toward said cathode, said last-named means comprising a suppressor electrode within said drift space and adjacent said first-named electrode, and means coupled to said suppressor electrode for maintaining said suppressor electrode at a positive potential relative to said first-named electrode.

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