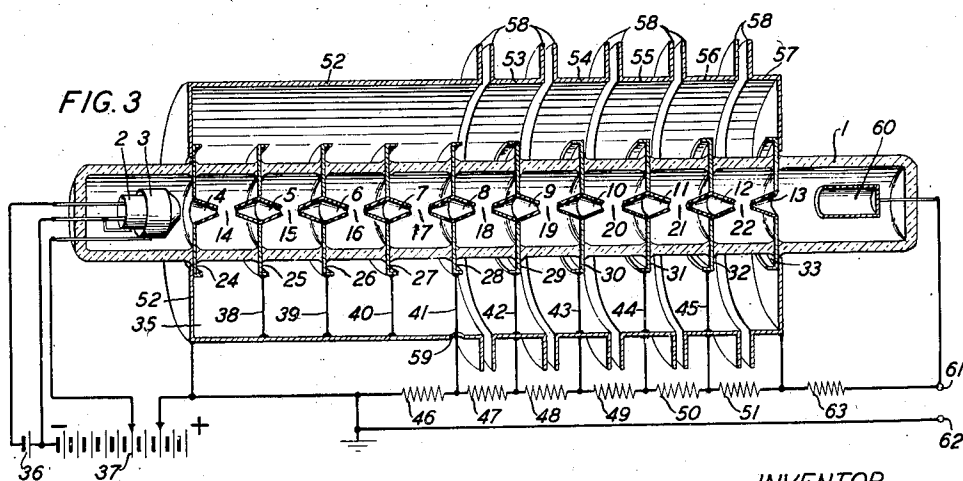
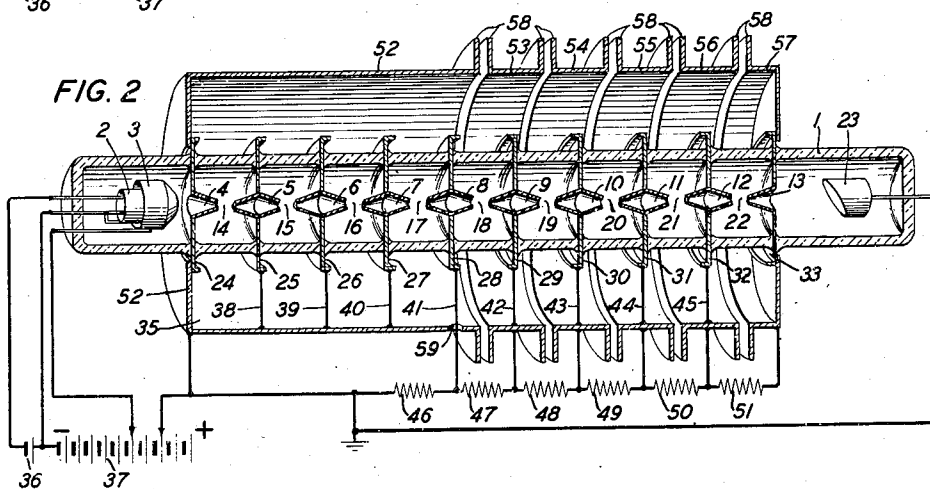
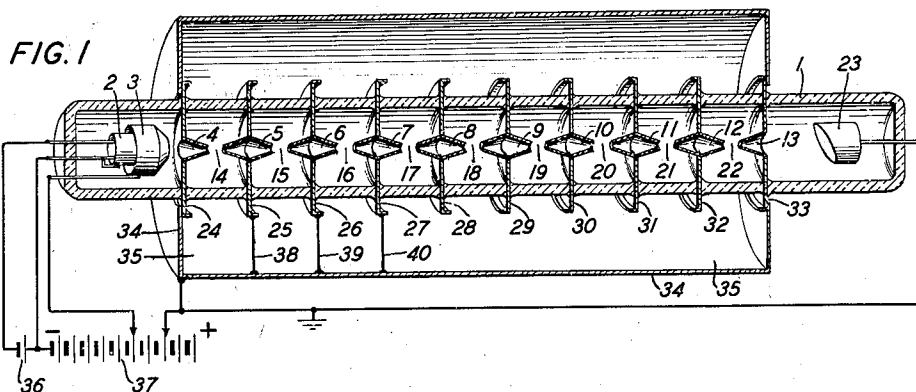


March 15, 1949.

A. L. SAMUEL
ELECTRONIC HIGH-VOLTAGE GENERATOR
DISCHARGE DEVICE
Filed May 27, 1943

2,464,349



INVENTOR
A. L. SAMUEL
BY *E. V. Briggs*
ATTORNEY

UNITED STATES PATENT OFFICE

2,464,349

ELECTRONIC HIGH-VOLTAGE GENERATOR
DISCHARGE DEVICE

Arthur L. Samuel, Summit, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application May 27, 1943, Serial No. 488,626

6 Claims. (Cl. 315-6)

1

This invention relates to electron beam devices, particularly those operating at ultra-high frequencies and utilized to produce high velocity electrons or high electric potentials.

A principal object of the invention is to provide a self-contained source of high velocity electrons which may be used to produce X-rays or for other purposes.

Another object is to provide a self-contained electronic source of high unidirectional potential.

A feature of the invention is that elaborate auxiliary apparatus is not required.

Another feature is that the external energy supply source need not be of extremely high potential.

An additional object is to provide a device of the type desired which is structurally compact.

It is known in the art to accelerate electrons by means of high frequency fields. Examples are the well-known cyclotron and the X-ray device of Sloan described in U. S. Patent 2,009,457. Also a device more closely related to the present invention which is arranged to produce a high voltage or high velocity electrons by first increasing the potential energy of the electrons without accelerating them is disclosed in a copending application of A. M. Skellett, Serial No. 377,458, filed February 5, 1941 and issued as United States Patent 2,407,296, September 10, 1946.

These and other similar devices require for their operation high frequency energy from an external source which is appropriately applied to electrodes of the device and of which the frequency must be properly correlated with the structure and adjustments of the device.

In the applicant's device to be described no external high frequency source is required. The high frequency is generated within the device itself and correlation between the high frequency energy and the means for its use is inherent in the design as the electron beam and the high frequency circuit are common to both the high frequency generating and utilizing means.

The detailed features of the device and the method of operation will be apparent from the following description and the accompanying drawings while the scope of the invention is defined in the appended claims.

In the drawings:

Fig. 1 shows a form of the invention as arranged to produce a high velocity electron beam;

Fig. 2 shows an alternative arrangement for the production of a high velocity electron beam, differing from Fig. 1 principally in the use of resistors to distribute electrode potentials; and

2

Fig. 3 shows a modification of the device of Fig. 2 to produce at suitable terminals a high unidirectional potential.

With reference to Fig. 1. Within the evacuated envelope 1 are located a cathode 2, an electron accelerating electrode 3, a series of generally tubular electrodes 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13 defining the gaps or spaces 14, 15, 16, 17, 18, 19, 20, 21 and 22 and a target and collecting electrode or anode 23. The electrodes 4 to 13 inclusive are supported by the metallic discs 24 to 33 inclusive sealed into the envelope 1 as has been shown also in U. S. Patent 2,281,717 issued to the applicant on May 5, 1942. Metallic member 34 is shown as cylindrical (though it may be of any suitable shape) with annular ends which connect with the discs 24 and 33 to enclose a space 35 and form a hollow electrical resonator. This resonator is bounded by the member 34, discs 24 and 33 and the electrodes 4 to 13 inclusive. The portions of space within the electrodes 4 to 13 are shielded from the resonator space 35 and are therefore external to the resonator space. The high frequency field associated with the resonator when it is energized extends into the spaces or gaps 14 to 22 where it may interact with an electron beam traversing them along the path between the cathode 2 and the target 23. The cathode 2 is suitably heated by energy from source 36 to emit electrons which may, under the influence of the electrodes 3, 4, 5, 6, 7 and 13 (positively charged from source 37), flow through the electrodes 4 to 13 and gaps 14 to 22 to the target 23.

It will be observed that the electrodes 5, 6 and 7 are maintained at the same direct potential as the resonator shell (or boundary) and the electrodes 4 and 13 attached thereto by the connections 38, 39 and 40. These connections are preferably of small dimensions (they may be relatively small wires) and should extend substantially radially in order to minimize interference with the electromagnetic waves within the resonator. If it is desired to make the potentials of these electrodes different from that of the resonator shell the leads 38, 39 and 40 may be passed through holes in the shell and connected to an external potential source. The resonator shell, the electrodes 4 to 7 and the means for projecting an electron stream through the gaps 14, 15 and 16 constitute a multigap oscillator whereby the resonator may be energized at its resonant frequency. This type of oscillator, with three gaps, has been shown in Fig. 1 of the applicant's copending application, Serial No.

412,067 filed September 24, 1941 and issued as United States Patent 2,403,025, July 2, 1946. The same type of oscillator utilizing two gaps has been shown in Figs. 1 and 5 of the copending joint application of the applicant and A. E. Anderson, Serial No. 386,794 filed April 4, 1941 and issued as United States Patent 2,405,175, August 6, 1946. Various numbers of gaps may be utilized in such an oscillator. In Fig. 1 three gaps 14, 15 and 16 are shown in the oscillator portion of the device. A greater or less number may be used depending upon what may be required to produce the necessary high frequency energy or for best operation of the device as a whole. The oscillator portion operates as described in the copending application, Serial No. 386,794 referred to above and its function is to produce the high frequency field in the resonator whereby some of the electrons attain high potential energy and may be highly accelerated. An oscillator operating on the same principle is described also in U. S. Patent 2,222,902, issued November 26, 1940, to W. C. Hahn wherein it is shown that to obtain maximum high frequency power the electron transit time between gaps should be a period which is that of an integral number of cycles of the high frequency less a fraction of a quarter of a cycle depending upon the number of gaps.

Electrodes 3 to 12 inclusive not used in the oscillator portion of the device are left floating, connected to each other and the rest of the structure only by leakage resistances. Under that condition these electrodes will become negatively charged with respect to the rest of the system, electrodes becoming progressively more negative in the direction of the last electrode 12. Each of these electrodes, then, is negative with respect to the one preceding it (electrode 8 is negative with respect to electrode 7 and electrode 9 is negative with respect to electrode 8 and so on) and the direct potential so impressed across each of the gaps 17 to 21 inclusive produces there, superposed upon the high frequency field a unidirectional electric field tending to retard the flow of electrons. Electrons crossing the gaps must do so by virtue of their velocity and assisted by the high frequency field when it is in the proper phase to oppose this unidirectional retarding field. This unidirectional field existing in each of the gaps 17 to 21 inclusive may be considered as a single stepped unidirectional field extending from electrode 7 to electrode 12. The term stepped is applied here because the potential does not change uniformly along the electron path but in steps at the gaps 17 to 21 and the electrons acquire a low potential in a number of steps as they traverse the series of electrodes as will now be explained.

In the oscillator portion of the system velocity variations are impressed upon the electron beam and at least some of the electrons having various velocities will pass through electrode 7. Certain of these electrons will enter gap 17 at such a phase of the high frequency field of the resonator as to tend to be accelerated by it and be thereby enabled to reach the interior of the first negatively charged electrode 8. Some of these electrons will drift through electrode 8, be again propelled by the high frequency field in gap 18 and be enabled to reach the interior of the still more negatively charged electrode 9 and so on through the rest of the electrodes up to electrode 12. It will be noted that a cumulative effect of the high frequency field on the electrons in the

gaps 17 to 21, inclusive is desired so that the electron velocity and the lengths of the electrodes 8 to 12 should be such that the electron transit time between the gaps is approximately the period of one cycle of the high frequency or of any whole number of cycles. The electron transit time through an electrode in this part of the device may therefore be somewhat longer than it is in the oscillator portion. Certain of the electrons finally reaching the interior of the highly negatively charged electrode 12 may then pass through the gap 22 at very high velocity under the influence of the positively charged electrode 13. These high velocity electrons emerging from electrode 13 then may strike the target anode 23 to produce X-rays or may be utilized in any desired manner.

It may be noted that all of the electrons in the beam leaving the cathode do not reach the target, so that the action of the device may be likened to that of a hydraulic ram in that a large number of electrons under the influence of a relatively low accelerating potential cause a part of those electrons to come under the influence of a much higher accelerating potential. This high accelerating potential is produced by successively depressing the potential of the higher velocity electrons by forcing them through the series of retarding electrostatic fields in the gaps 17 to 21. The electrons finally leave the most negative electrode 12 under the influence of the high accelerating potential between negative electrode 12 and positive electrode 13. It may be further noted that in the operation of the entire device the net effect in the oscillator portion (comprising gaps 14, 15 and 16) is the generation of high frequency energy to excite the resonator to produce the high frequency field which extends into the gaps between the electrodes while in the part of the device comprising gaps 17 to 21 inclusive the net effect is to store energy in the electron stream by successively depressing the potential of the electrons which continue along the path. In other words, in the oscillator portion, preponderantly, energy is transferred from the electron stream (energized from the relatively low potential source 37) to the high frequency field and further along the electron path of the device, preponderantly, energy is transferred from the high frequency field to the electron stream in the form of potential energy. This potential energy may be used to effect a high acceleration of the electrons as in Fig. 1 or to provide a high potential direct current source as in Fig. 3 which will be explained later. Thus there may be produced within the device itself direct current energy at a very high potential while operation of the device is from a power source of much lower potential as indicated at 37 in the figures.

Fig. 2 shows a modification of Fig. 1 in which the electrodes not used in the oscillator portion of the device are not left completely insulated except for possibly uncertain leakage resistance but are connected together and to ground with high resistance resistors to more definitely divide between them the high negative potentials developed due to the accumulation of charges upon them. This particular feature is shown in the somewhat similar device disclosed in the above-mentioned copending application Serial No. 377,458 filed February 5, 1941 by A. M. Skellett.

In Fig. 2 the envelope 1, cathode 2, electrodes 3 to 13 and the rings 24 to 23 are the same as in Fig. 1. However, the resonator shell member 34 of Fig. 1 is divided into a number of parts

5

52 to 57. For high frequencies these parts form a continuous conducting shell enclosing the space 35 by virtue of the capacitances between the spaced flanges 58 which are provided for that purpose. For direct potentials the shell portions 52 to 57 are insulated from each other except for the connections through the high resistances 48 to 51. The electrodes 5, 6 and 7 which function in the oscillator portion of the device are connected to the shell portion 52 and so to the source 37 by leads 38, 39 and 40 as in Fig. 1. Electrodes 8 to 12 (which are "floating" in Fig. 1) and 13 are connected through leads 41 to 45 and resistors 46 to 51 to the source 37 and ground. The leads 42 to 45 connect also to the resonator shell portions 53 to 56, respectively so that these shell portions acquire the same potentials as the electrodes 9 to 12, respectively. This is a design feature to facilitate insulating the structure for the high potentials developed but is not essential. To show an alternative method of construction the lead 41 connecting to electrode 8 is shown passing through an opening 59 in the shell portion 52 and the part of the portion 52 radially outward from electrode 8 is not isolated by spaced flanges (such as 58) as are the portions 53 to 57 radially outward from electrodes 9 to 13. An alternative construction therefore is to use a shell member such as 34 in Fig. 1 without the flanges 58 and pass all of the leads 41 to 45 to the resistors 46 to 51 through openings such as 59. It is obvious that ordinarily when the spaced flange type of construction illustrated in Fig. 2 is employed the shell would be further sectionalized opposite electrode 8 by another pair of flanges and the opening 59 would not then be required as lead 41 would connect with an isolated shell portion the same as leads 42 to 45. As mentioned above the resistors 46 to 51 serve to equalize the distribution of voltage between the electrodes. They are made high enough, however, to permit the electrodes to become charged to relatively high potentials with small current flow in them.

Operation of the Fig. 2 arrangement is the same as that of Fig. 1, the electron stream generating high frequency energy in the resonator in the oscillator portion of the device comprising gaps 14, 15 and 16 and the high frequency field of the resonator in turn acting upon the electron stream in the other portion of the device comprising gaps 17 to 22 to produce high accelerating potentials and high velocity electrons.

It may be noted that in Fig. 1 the electrode 13 is at the same potential as the cavity shell and the target 23 so that the electrons are highly accelerated between electrodes 12 and 13 while in Fig. 2 the electrode 13 is isolated in the same manner as electrodes 8 to 12 so that it becomes the most highly negatively charged electrode and the electrons are accelerated between the electrode 13 and the target 23. In either case high velocity electrons strike the target 23.

Fig. 3 shows a device like that of Fig. 2 but arranged to utilize the high voltage developed rather than high velocity electrons. An electron collector 60 to serve as an anode is substituted for the target 23 and is connected to electrode 13 and resistor 51 through an additional resistor 63. The collector is not connected directly to ground and source 37 as was the target 23, but rather, through the resistances and two terminals (61 connected to the collector and 62 connected to ground and source 37) are provided between which the high direct potential developed is available for any desired use.

6

Operation of the arrangement of Fig. 3 is similar to that of Figs. 1 and 2 in that there is an oscillator portion of the device comprising gaps 14, 15 and 16 and a portion where the high frequency field of the resonator propels certain of the electrons through the retarding fields of the series of negatively charged electrodes 8 to 13 and 60 so that across the whole series a potential much higher than that of the source 37 is produced.

The essential difference between this Fig. 3 arrangement and that of Figs. 1 and 2 is that this high potential is impressed across the high resistance 46 to 51 and 63 and may be utilized directly at the terminals 61 and 62 whereas in Figs. 1 and 2 the high potential is employed in the device to produce high velocity electrons which may be utilized to produce X-rays or for any other desired purpose.

In the previously mentioned copending application Serial No. 377,458 a device is shown for producing a high potential by a method somewhat similar to that employed in Fig. 3. However, that device does not include means for generating with the electron beam the high frequency energy required.

It may be noted that in Figs. 1 and 2 the lead from the target 23 and in Fig. 3 the lead from terminal 62 may, if desired, be connected to the cathode directly rather than to ground and thence to the cathode through the source 37 as shown. If connected to the cathode directly the accelerating potential or the potential at the terminals 61 and 62 will be increased by the potential of source 37.

What is claimed is:

1. An electronic device comprising means for producing an electron beam, a plurality of generally tubular electrodes in axial alignment therewith spaced from each other and adapted to be axially traversed by the electron beam and a hollow electrical resonator having a shell which includes the said spaced electrodes and which when excited impresses a high frequency field to interact with the electron beam in the axial spaces between the said electrodes, some of the said electrodes adjacent to each other being electrically interconnected by leads having low direct current resistances and others of the said electrodes adjacent to each other are electrically interconnected through paths having direct current resistances substantially higher than the resistances of said lead interconnections.

2. An electronic device comprising an evacuated envelope including means for producing a high frequency electric field within said envelope, including means for projecting a beam of electrons along a path within said envelope through said field whereby the electrons in the beam may interact with the electric field, and a plurality of shielding means of conducting material spaced along the electron path within the said envelope whereby the electron beam is shielded from the high frequency field except at the spaces between the shielding means, a plurality of the said shielding means adjacent to each other along one portion of the electron path being interconnected by leads having low direct current resistances and another plurality of the said shielding means along another portion of the electron path being interconnected by paths having direct current resistances substantially higher than said low resistances.

3. An electronic device comprising, an electron tube having a cathode, an anode and a plurality of electrodes in spaced relation between the cath-

ode and anode, and including means for projecting a beam of electrons from the cathode to the anode along a path in proximity to the said spaced electrodes and the spaces therebetween, a hollow electrical resonator capable of being excited at its resonant frequency by the electron beam and the boundary of which includes the said spaced electrodes, whereby a high frequency field may interact with the electron beam in the said spaces between the electrodes, some of the said electrodes located in the region toward the cathode and adjacent to each other being electrically interconnected by leads having low direct current resistances and others of the said electrodes located in a region nearer to the anode and adjacent to each other being electrically interconnected through paths of direct current resistance substantially higher than said low resistances, the lengths of the said electrodes as measured along the said electron path corresponding to an electron transit time between corresponding points on adjacent electrodes of substantially between the periods of $n + \frac{3}{4}$ and $n + 1$ cycles of the said resonant frequency where n is an integral number of cycles including zero.

4. An electronic device comprising, an electron tube having a cathode, an anode and a plurality of electrodes in spaced relation between the cathode and anode, and including means for projecting a beam of electrons from the cathode to the anode along a path in proximity to the said spaced electrodes and the spaces therebetween, a hollow electrical resonator capable of being excited at its resonant frequency by the electron beam and the boundary of which includes the said spaced electrodes, whereby a high frequency field may interact with the electron beam in the said spaces between the electrodes, some of the said electrodes located in the region toward the cathode and adjacent to each other being electrically interconnected by leads having low direct current resistances and having lengths as measured along the said electron path corresponding to an electron transit time between corresponding points on adjacent electrodes of substantially between the periods of $n + \frac{3}{4}$ and $n + 1$ cycles of the said resonant frequency where n is an integral number of cycles including zero and others of the said electrodes located in a region nearer to the anode and adjacent to each other are electrically separated by paths having direct current resistances substantially higher than said low resistances and have lengths as measured along the said electron path corresponding to an electron transit time between corresponding points on adjacent electrodes of substantially the period of $n + 1$ cycles of the said resonant frequency where n is an integral number of cycles including zero.

5. An electronic device comprising an evacuated envelope including means for producing a high frequency electric field within said envelope, including means for projecting a beam of electrons along a path within said envelope through said field whereby the electrons in the beam may interact with the said electric field and a plurality of shielding means of conducting material spaced along the electron path within the said envelope capable of collecting electrons and of shielding the electron beam from the electric field except at the spaces between the shielding means, a plurality of the said shielding means adjacent to each other along one portion of the electron path having low direct current resistance interconnecting leads and another plurality of the said shielding means along another portion of the electron path having substantially higher direct current resistance interconnecting electrical paths.

6. An electronic device comprising an electron tube having a cathode, an anode and a plurality of electrodes in spaced relation therebetween, means comprising a source of direct current potential connected to the cathode for projecting a beam of electrons from the cathode along a path in proximity to the said spaced electrodes and the spaces therebetween, a hollow electrical resonator capable of being excited at its resonant frequency by the electron beam and which includes the said spaced electrodes whereby when the resonator is excited there is impressed a high frequency electric field to interact with the electron beam in the said spaces between the electrodes, some of the said electrodes in the region toward the cathode being connected by leads for direct current to the said potential source, others of the said electrodes farther along the electron path from the cathode having direct current paths which include substantial resistance between each other and between them and the said potential source.

ARTHUR L. SAMUEL.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,222,902	Hahn	Nov. 26, 1940
2,281,717	Samuel	May 5, 1942
2,284,751	Linder	June 2, 1942
2,325,865	Litton	Aug. 3, 1943
2,407,298	Skellett	Sept. 10, 1946

OTHER REFERENCES

Proc. I. R. E.—Feb. 1939, vol. 27, No. 2, page 114.