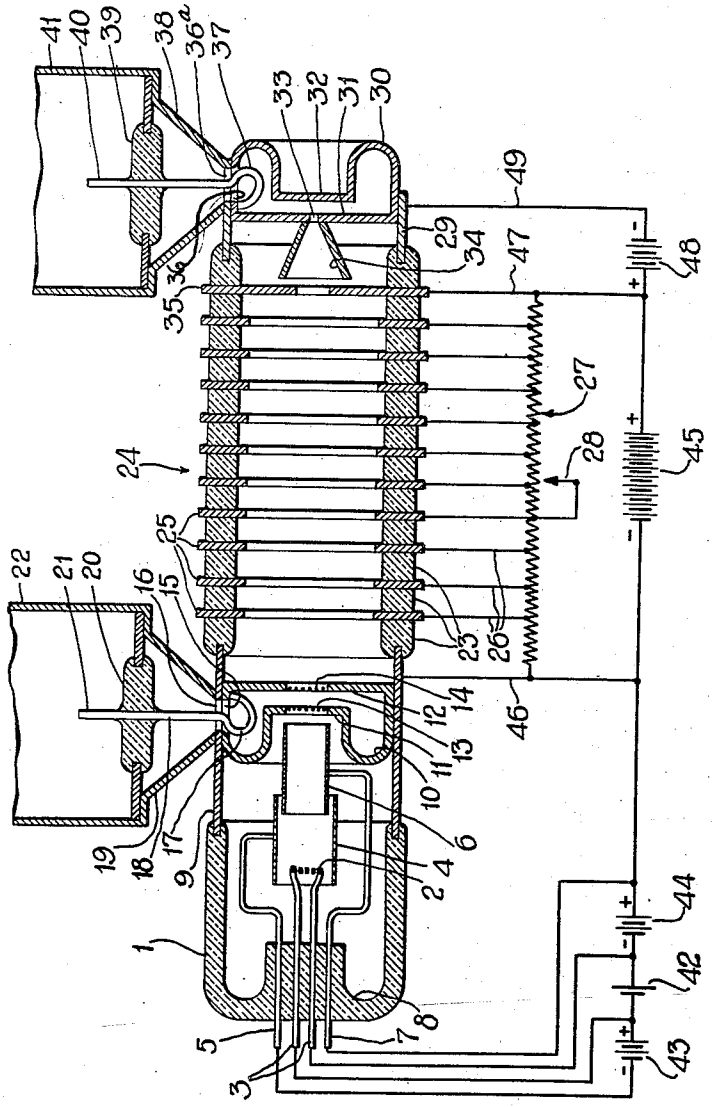
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ELECTRICAL DISCHARGE DEVICE
HAVING CAVITY RESONATORS
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ELECTRICAL DISCHARGE DEVICE HAVING CAVITY RESONATORS

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This invention relates to electrical discharge devices adapted for ultra-high frequency use and of the type in which a beam of charged particles is subjected to the action of an alternating electric field. More particularly, the invention is concerned with a novel electric discharge device, which may be employed as an ultra-high frequency oscillator or amplifier and can be operated safely at higher output rates than prior devices for the same purpose.

At the present time, electron discharge devices functioning in accordance with the principle of velocity modulation are well known and, in such devices as the Klystron, an electron beam from a source passes through aligned openings, usually containing grids, in opposite walls of a cavity resonator in which the beam is subjected to the action of an alternating field produced by oscillations within the resonator. The dimensions of the resonator and the frequency of the oscillations therein are such that, in their passage between the grids, some of the electrons are accelerated, others are decelerated, while still others may leave with their velocity substantially unchanged. Beyond the resonator, the electrons enter a field-free space termed a "drift tube" and in their passage through the tube the differences in the velocities of the electrons cause them to become bunched. The bunches of electrons pass from the drift tube through a grid into a second cavity resonator which resonates preferably at the same frequency as the first, and, in the second resonator, the bunches of electrons set up an alternating field from which energy may be absorbed. If the device is employed as an oscillator, some of the absorbed energy is fed back to the first resonator to maintain the field therein, while, if the device is used as an amplifier the field in the first resonator is maintained by energy from the signal to be amplified and the energy absorbed from the second resonator passes to an output circuit.

In such a velocity modulation device, the resonators and the drift tube are all at the same D. C. potential and the electrons in the beam receive the major part of their acceleration before they enter the first or "buncher" resonator and they are not accelerated in the space between the resonators. The resonators have small openings, so that their efficiency may not be too greatly impaired, and the grids, when used in the openings, provide the desired close coupling between the beam and the resonators. Since the beam will burn out any grid through which it passes if the current density of the beam is too great and the electron speed too high, the beam passing through the first resonator must be restricted as to either

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current density or electron speed in order to protect the grids.

Some of the limitations upon the prior devices arise from space charge effects. As is well known, it is difficult to maintain a beam of charged particles, which is of small diameter, high intensity, and substantial length. Such a beam may be focused at one point along its axis to limit its diameter, but, as the beam travels along, it tends to expand because of the space charge effect. This tendency assumes considerable importance in prior devices.

The present invention is directed to the provision of a novel electric discharge device capable of use as an oscillator or amplifier, which, although involving the use of a beam of charged particles, functions differently from and is superior to velocity modulation devices of the type above described. In its broadest aspect, the new device includes a source of charged particles, means for intermittently cutting off the flow of particles so that the particles are grouped, means for accelerating the groups of particles, and means for retarding, and thereby absorbing energy from the groups of accelerated particles. Preferably, the charged particles employed are electrons and the means for cutting off the flow thereof is an alternating field within a cavity resonator. Beyond the resonator, the groups of electrons produced by the action of the field on the electron beam are accelerated by an electrode or a series of electrodes spaced along the path of travel of the electron groups and maintained at proper potentials. After having thus been accelerated, the electron groups are focused by appropriate means and directed into a second cavity resonator in which they set up an alternating field from which energy is absorbed. Since the beam of electrons enters the first resonator at relatively low velocity, grids may be mounted in the openings in the resonator without danger of being burned out, even though the beam is of high current density. The grouping of the electrons takes place wholly within the first resonator and it is possible to accelerate the groups in the space between the two resonators and also to focus the groups immediately prior to their entering the second resonator. The groups, accordingly, enter the second resonator at high velocity and high current density, so that a correspondingly large amount of energy may be absorbed from the alternating field which they set up within the second resonator. At the same time, the possibility of focusing the groups about to enter the second resonator permits the use of a small opening into the second resonator with resultant increase in efficiency and without the necessity of

employing a grid in the opening to obtain close coupling.

For a better understanding of the invention, reference may be had to the accompanying drawing in which the single figure is a partly diagrammatic longitudinal sectional view of an embodiment of the invention in the form of an amplifier.

The device illustrated in the drawing comprises an end section 1, made of glass and containing a cathode filament 2 supplied with current through leads 3. The filament lies within a cylindrical focusing electrode 4, to which lead 5 is connected, and an accelerating electrode 6 lies coaxially with the electrode 4 and is partially telescoped therewith. Electrode 6 is connected to a lead 7. The several leads pass through a press sealed in the end wall 8 of the section 1.

A tubular metal section 9 is sealed at one end on the cylindrical end of the section 1 and within the metal section is a cavity resonator 10, which has parallel walls 11, 12 lying at right angles to the axis of electrode 6 and formed with openings aligned with that electrode and containing grids 13, 14, respectively. The resonator has a peripheral opening 15 aligned with a similar opening 16 through the wall of section 9, and a coupling loop 17 lies within the resonator and has a lead 18, which extends through a conical connection 19 and through an insulating support 20 to terminate as a probe 21 within a hollow wave guide 22.

The other end of the metal section 9 is sealed on a cylindrical glass section 23 at one end of a chamber generally designated 24 and formed of alternate glass sections 23 and annular metal discs 25. The discs are of such dimensions as to project beyond the glass sections both inwardly and outwardly, and the glass sections and discs are aligned to produce a tubular structure axially aligned with the openings through walls 11, 12 of the cavity 10. The several discs serve as accelerating electrodes and they are provided with leads 26 connected to space points on a voltage dividing resistor generally designated 27. This resistor is provided with a selector switch, conventionally indicated at 28, which may be used for phasing purposes.

At the end of the insulating structure remote from the resonator 10, the structure is connected to a tubular metal section 29, the open end of which is closed by a cavity resonator 30, which is similar to resonator 10 and resonates at the same frequency. The resonator 30 has parallel walls 31, 32 lying transverse to the axis of the device, and wall 31 contains a small central opening 33. A focusing electrode 34 is mounted on the outside of wall 31 around opening 33 and the adjacent disc 35 within the structure is formed with a smaller central opening than the other discs and cooperates for focusing purposes with the electrode 34.

Resonator 30 is formed with a peripheral opening 36 aligned with an opening 36a through the wall of section 29, and the resonator contains an output coupling loop 37, the end of which projects through opening 36 and through a conical connection 38 to pass through an insulating support 39 and terminate as a probe 40 within a hollow wave guide 41.

The leads 3 of filament 2 are connected to a voltage source 42, and lead 5 of the focusing electrode 4 is connected to the negative side of a voltage source 43. Lead 7 of accelerating electrode 6 is connected to the positive side of a voltage source 44. A voltage source 45 is connected across the resistor 27, and the negative side of the source is connected by connection 46 to the metallic section 9, and through it, to the resonator 10. The several discs 25 are connected to taps on the resistor and the focusing disc 35 is connected to the positive side of the voltage source 45 by a connection 47. The focusing electrode 34 is connected to the negative side of a voltage source 48, provided for that focusing purpose, by a connection leading to the cylindrical section 29, with which electrode 34 is in electrical connection through the wall of cavity 30. The positive side of source 48 is connected to the positive side of resistor 27.

In the operation of the device as an amplifier, the filament is heated and emits electrons, which are focused by electrode 4 to form a beam and are accelerated by electrode 6 to a relatively low velocity. The signal to be amplified is applied to the wave guide 22 and the resonators 10 and 30 may be adjusted by conventional means not shown so that they will resonate at the frequency of the signal. The coupling loop 17 then functions in response to the signal to cause resonator 10 to resonate. The electrical values employed are so chosen that the alternating electric potential between the grids 13 and 14 of resonator 10 is high relative to the voltage represented by the speed of the electrons entering the resonator and, as a consequence, the potential between the grids acts during one half cycle to prevent substantially all flow of electrons through the resonator, while permitting the electrons to emerge from the resonator into the structure 24 during the next half cycle. The electrons will, accordingly, enter the structure 24 in the form of groups and the beam made up of the groups will be accelerated by the successively higher potentials applied to the electrodes 25. At the end of the chamber 24, the beam is focused by the action of electrodes 34 and 35 energized by the voltage source 48.

The groups of electrons leaving chamber 24 enter the second cavity resonator 30 through the opening 33. This resonator resonates at the same frequency as cavity 10 and the passage of the groups of electrons across resonator 30 from the opening to their point of impingement on the end wall 32 of the resonator causes the latter to resonate. The alternating field within resonator 30 retards the electrons, so that energy is given up to the resonator by the electrons and is then transmitted by the coupling loop 37 to the output wave guide 41.

From the foregoing, it will be apparent that the new device differs from prior devices for the same general purpose in numerous respects. As distinguished from prior practice, the electron beam enters the first resonator of the device at relatively low velocity and may, therefore, be of relatively high current density without danger of burning out the grids in the resonator openings. The grouping of the electrons takes place wholly within the first resonator, and no drift tube, within which bunching of electrons of different velocity may take place, is required. The two resonators are electrically separated and the chamber between them insulates them from one another and defines the space in which the beam may be subjected to accelerating potentials. Within the chamber, the beam made up of groups of electrons is given a high velocity and at the exit end of the chamber, the beam is focused, so that, even though the beam is of high intensity, the opening into

the second resonator may be small and, accordingly, no grid in the opening is necessary to maintain the desired close coupling between the beam and resonator. Also, since no grid is used, the speed of the electrons and the intensity of the beam may be much higher than would be permissible, if a grid were present.

The most desirable spacing of grids 13, 14, the size of the opening 33, the values of the several voltage sources, and similar features depend on the frequency at which the device is to operate, the output desired, and various considerations of that sort. In general, however, it may be said that the operation of the device improves as frequency is increased. The specific construction illustrated is a desirable physical embodiment of the invention, but devices of other constructions operating on the same principles will readily occur to those familiar with such apparatus.

I claim:

1. An electrical discharge device adapted for ultra-high frequency use, which comprises an evacuated envelope, means within the envelope for producing a beam of charged particles traveling along a rectilinear path within the envelope at relatively low velocity, means within the envelope defining a cavity resonator having aligned openings through which the particles pass, means for maintaining an oscillating field within the resonator which acts on the beam to cause the particles to be formed into groups, means for subjecting the particles traveling through the envelope beyond the resonator to a constant rectilinear field to accelerate the groups of particles without substantially changing their direction, said means including a plurality of electrodes distributed within the envelope along the path of the particles, potential-source means connected to said electrodes for maintaining them at increasing potentials with respect to the beam-producing means, and means within the envelope in the path of travel of the particles beyond the group accelerating means for absorbing energy from the accelerated groups, said absorbing means including a cavity resonator having an opening through which the groups pass into the resonator.

2. An electrical discharge device adapted for ultra-high frequency use, which comprises an evacuated envelope, means within the envelope for producing groups of charged particles traveling at relatively low velocity along a rectilinear path, means within the envelope for subjecting the groups of particles moving along said path to a constant rectilinear field to accelerate the groups without substantially changing their direction, said means including a plurality of electrodes distributed within the envelope along the path of the particles, potential-source means connected to said electrodes for maintaining them at increasing potentials with respect to the means for producing the groups of charged particles, and means within the envelope beyond the electrodes and spaced therefrom for absorbing energy from the accelerated groups of particles, said absorbing means including a cavity resonator having an opening through which the groups of particles may enter the resonator.

3. An electrical discharge device adapted for ultra-high frequency use, which comprises an evacuated envelope, means within the envelope for producing a beam of charged particles traveling along a rectilinear path within the envelope at relatively low velocity, a cavity resonator mounted on the envelope wall and having walls extending across the path of the beam, the resonator walls having aligned openings through which the beam may pass, a second cavity resonator mounted on the envelope wall and having at least one wall extending across the path of the beam, said resonator wall having an opening through which the beam may enter the resonator, means for maintaining an oscillating field within the first resonator which is adapted to act on the beam passing through the resonator to cause the particles to be formed into groups, and means for subjecting the groups of particles to a constant rectilinear field to accelerate the groups without substantially changing their direction including a plurality of electrodes mounted on the envelope wall and spaced along the path of the groups of particles between the resonators and potential-source means connected to said electrodes for maintaining them at increasing potentials with respect to the beam-producing means.

4. An electrical discharge device adapted for ultra-high frequency use, which comprises an evacuated envelope, means within the envelope for producing a beam of charged particles traveling along a rectilinear path within the envelope at relatively low velocity, a cavity resonator mounted on the envelope wall and having walls extending across the path of the beam, the resonator walls having aligned openings through which the beam may pass, a second cavity resonator mounted on the envelope wall and having at least one wall extending across the path of the beam, said resonator wall having an opening through which the beam may enter the resonator, means for maintaining an oscillating field within the first resonator which is adapted to act on the beam passing through the resonator to cause the particles to be formed into groups, means for subjecting the groups of particles to a constant rectilinear field to accelerate the groups without substantially changing their direction including a plurality of electrodes mounted on the envelope wall and spaced along the path of the groups of particles between the resonators, and potential-source means connected to said electrodes for maintaining them at increasing potentials with respect to the beam-producing means, and means for focusing the accelerated groups of particles approaching the opening into the second resonator.

5. An electrical discharge device adapted for ultra-high frequency use, which comprises an evacuated envelope, means within the envelope for producing a beam of charged particles traveling along a rectilinear path within the envelope at relatively low velocity, a cavity resonator mounted on the envelope wall and having walls extending across the path of the beam, the resonator walls having aligned openings through which the beam may pass, a second cavity resonator mounted on the envelope wall and having at least one wall extending across the path of the beam, said resonator wall having an opening through which the beam may enter the resonator, means for maintaining an oscillating field within the first resonator which is adapted to act on the beam passing through the resonator to cause the particles to be formed into groups, and a plurality of electrodes within the envelope distributed along the space between the resonators, potential-source means connected to said electrodes for maintaining them at increasing

potentials with respect to the beam-producing means effective to subject the groups of particles to a constant rectilinear field which accelerates the groups without substantially changing their direction.

6. An electrical discharge device adapted for ultra-high frequency use, which comprises an evacuated envelope, means within the envelope for producing groups of charged particles traveling at relatively low velocity along a rectilinear path, means within the envelope for subjecting the groups of particles moving along said path to a constant rectilinear field to accelerate the groups without substantially changing their direction, said means including a plurality of electrodes within the envelope and spaced along the path of the groups of particles and potential-source means connected to said electrodes for maintaining them at increasing potentials with respect to the means for producing the groups of charged particles, means within the envelope beyond the accelerating means and spaced therefrom for absorbing energy from the accelerated groups of particles, said absorbing means including a cavity resonator having an opening through which the groups of particles may enter the resonator, and means within the envelope for focusing the accelerated groups of particles as they approach the opening in the resonator of the absorbing means.

7. An electrical discharge device adapted for ultra-high frequency use, which comprises an evacuated envelope, means within the envelope for producing groups of electrons traveling at relatively low velocity along a rectilinear path, means within the envelope including a plurality of electrodes spaced along said path for subjecting the groups of electrons moving along said path to a constant rectilinear field to accelerate the groups without substantially changing their direction, potential-source means connected to said electrodes for maintaining them at increasing potentials with respect to the means for producing the groups of electrons, means within the envelope beyond the accelerating means and spaced therefrom for absorbing energy from the accelerated groups of electrons, said absorbing means including a cavity resonator having an opening through which the groups of electrons may enter the resonator, and means within the envelope between the group accelerating means and the resonator of the absorbing means for focusing the accelerated groups of electrons as they approach the opening in said resonator.

8. An electrical discharge device adapted for ultra-high frequency use, which comprises an evacuated envelope, means within the envelope for producing groups of charged particles traveling at relatively low velocity along a rectilinear path, a plurality of electrodes mounted on the envelope wall and encircling and spaced along the path of the groups of particles, potential-source means connected to said electrodes for maintaining them at increasing potentials with respect to the means for producing the groups of charged particles, whereby the velocity of the particles traveling along said path is accelerated without substantially changing the direction of movement of the groups, and means beyond the electrodes for absorbing energy from the accelerated groups, said absorbing means including a cavity resonator mounted on the envelope wall and having an opening through which the groups of particles may enter the resonator.

9. An electrical discharge device adapted for ultra-high frequency use, which comprises an evacuated envelope, means within the envelope for producing a beam of electrons traveling along a rectilinear path within the envelope at relatively low velocity, means for forming the electrons in the beam into groups, said means including a cavity resonator mounted on the wall of the envelope and having walls extending across the path of the beam, said resonator walls having openings through which the beam passes, means for absorbing energy from the groups of electrons, said means including a cavity resonator mounted on the envelope wall and having a wall extending across the path of travel of the groups of electrons and provided with an opening through which the groups may enter the resonator, the walls of the envelope between the resonators being made up of alternate annular sections of insulation and annular metallic disc electrodes, and potential-source means connected to said electrodes for maintaining them at increasing potentials with respect to the beam-producing means effective to subject the groups of electrons to a constant rectilinear field accelerating the groups without substantially changing their direction.

10. An electrical discharge device adapted for ultra-high frequency use, which comprises an evacuated envelope, means within the envelope for producing a beam of electrons traveling along a rectilinear path within the envelope at relatively low velocity, means for forming the electrons in the beam into groups, said means including a cavity resonator mounted on the wall of the envelope and having walls extending across the path of the beam, said resonator walls having openings through which the beam passes, and grids in said openings, means for absorbing energy from the groups of electrons, said means including a cavity resonator mounted on the envelope wall and having a wall extending across the path of travel of the groups of electrons and provided with an unobstructed opening through which the groups may enter the resonator, means between the resonators for subjecting the groups of electrons to a constant rectilinear field to accelerate the electrons without substantially changing their direction, said accelerating means including a plurality of electrodes mounted in spaced relation on the envelope wall between the resonators, potential-source means connected to said electrodes for maintaining them at successively higher potentials along the path of travel of the electrons with respect to the beam-producing means, and means mounted on the envelope wall between the electrodes and the resonator of the absorbing means for focusing the groups of electrons into the resonator of the absorbing means through said unobstructed opening.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,156,813	Kautz	May 2, 1939
2,254,796	Doring	Sept. 2, 1941
2,272,165	Varian et al.	Feb. 3, 1942
2,280,026	Brown	Apr. 14, 1942
2,281,935	Hansen et al.	May 5, 1942
2,293,151	Linder	Aug. 18, 1942
2,405,611	Samuel	Aug. 13, 1946