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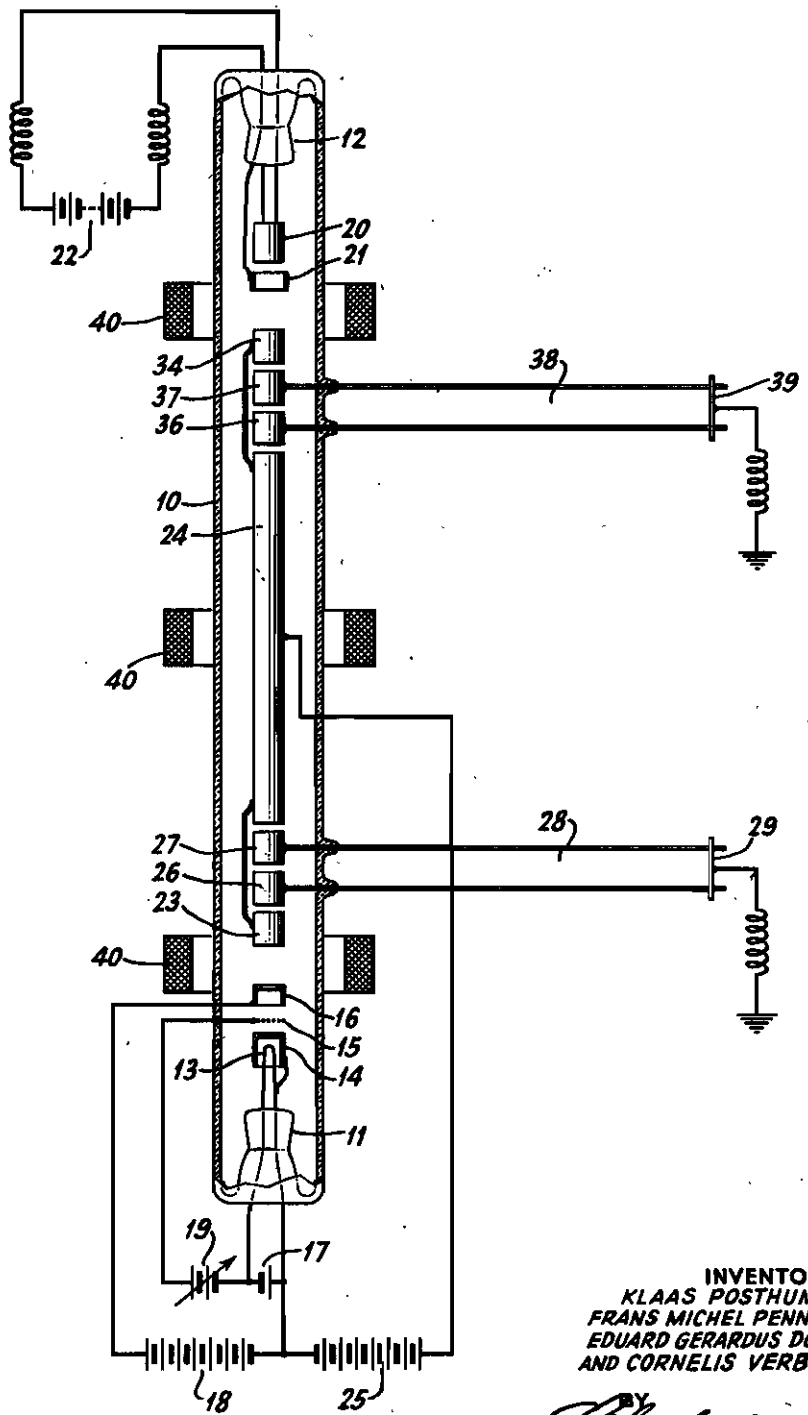

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ELECTRON DISCHARGE DEVICES

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This invention relates to an electron discharge device utilizing an electron beam and suitable for use at very high frequencies, particularly to such a device in which the electrons in the beam are subjected to so-called velocity modulation and from which energy is abstracted by induction.

This invention relates to a device comprising a discharge tube in which the electrons are concentrated in a beam and traverse a control space which is bounded by two electrodes which will be referred to hereinafter as circumscribing electrodes. In the device to which the invention relates a speed or velocity control of the electrons can be brought about in the said space by means of an electrode, whereas the speed variations are converted outside the said space into variations in density.

According to the invention, the control space circumscribed by the circumscribing electrodes encloses two speed or velocity control electrodes to which are supplied control voltages of identical frequency but having a phase displacement of 180°.

The initial speed of the electrons and the length of the speed-control electrodes are preferably so chosen that the transit time of the electrons between two neighboring slits is a quarter of or half the oscillation period of the control voltages.

The device according to the invention, in which the control space bounded by the circumscribing electrodes encloses two control electrodes, has the advantage that at a given length of the speed-control electrodes the same effect is obtained as is obtained by means of a device comprising one speed-control electrode in the control space but in which the control voltage is doubled.

In addition, the device according to the invention is very advantageous if a Lecher-wire system comprising two parallel conductors is connected to the control electrodes in a symmetrical manner.

In order that the invention may be clearly understood and readily carried into effect it will now be described more fully with reference to the accompanying drawing, in which one form of construction of a device embodying it is illustrated.

The discharge tube shown in the figure comprises an exhausted glass bulb 10 containing a stem 11 at one of its ends and a stem 12 at the other end. The bulb accommodates means for generating an electron beam having a substantially constant intensity and electron speed. For this purpose use may be made of various means; the means illustrated in the drawing are to be regarded as an example only. In the present case the device for generating an electron beam comprises a heating filament 13, which is surrounded by a cathode 14, a control electrode 15 and an accelerating anode 16.

During the operation of the device the filament 13 is heated by current received from a battery 17 and the accelerating anode 16 is supplied with a suitable voltage which is positive relatively to the cathode and is derived from a source of voltage 18. The control electrode 15 is supplied with a preferably variable bias which is positive relatively to the cathode and may be furnished by a source of voltage 19.

At the other end of the tube is arranged an anode 20 whose function is to collect the electrons emitted by the cathode and which will be referred to as the "collecting electrode". On the cathode side of the collecting electrode 20 is arranged a cylindrical electrode 21 which serves respectively for collecting or repelling the secondary electrons emitted by the collecting electrode 20 and which is therefore given a potential, which is positive or negative relatively to the collecting electrode and is derived from the source of voltage 22.

Preferably, a number of coils 40 are arranged for the obtainment of a sharp concentration of the electron beam.

The control space in which the speed of the cathode ray beam can be controlled is bounded by two tubular electrodes 23 and 24 which circumscribe the path of the electron beam and are referred to hereinafter as circumscribing electrodes. In the case illustrated these circumscribing electrodes are grounded and are given a high potential which is positive relatively to the cathode and which is derived from a source of voltage 25.

According to the invention, the control space bounded by the circumscribing electrodes 23 and 24 encloses, either within or without the bulb 10, two speed-control electrodes 26 and 27 which are supplied with control voltages of the same frequency having a relative phase displacement of 180°. Due to the potential variation in the control space relatively to the limiting potentials of this space speed control or in fact velocity modulation of the electron beam is obtained.

The electrons which at a given moment are enclosed in the control space between two electrodes, for example the electrodes 23 and 26, are accelerated or delayed according as the voltage of the electrode into which the electron enters, for example the electrode 26, is positive or negative at that moment relatively to that of the electrode 23 which the electron leaves, while the same occurs with the electrons which are enclosed between the electrodes 26 and 27 or 27 and 24. In

the device according to the invention in which the circumscribing electrodes are separated by two speed-control electrodes which are supplied with voltages having a phase displacement of 180°, the speed or velocity modulation obtained is a maximum if the initial speed of the electrons and the axial length of the electrodes **26** and **27** are such that the transit time of the electrons between neighboring slits or gaps in the control space is π, wherein 2π is equal to the oscillation period of the control oscillation. In this case, the electrons which enter into the control space at the electrode **23** will leave the control space at the electrode **24** about an entire cycle of the supplied control voltage later, whereas in the control space the passage from the electrode **26** to the electrode **27** ensues approximately within half a period. An electron which enters into the electrode **26** at a moment when this electrodc has the maximum positive voltage, for example a voltage E, relatively to the circumscribing electrodes **23** and **24** will therefore leave the electrode **27** at a moment when this electrode has the maximum negative voltage relatively to the circumscribing electrodes so that both on entering and on leaving the control space the electron is accelerated under the influence of the control voltage E. In addition, the passage from the electrode **26** to the electrode **27** ensues for the relevant electron at the moment when there exists a voltage 2E between the electrodes **26** and **27**, the electrode **27** being positive relatively to the electrode **26**, so that on passing from the electrode **26** to the electrode **27** the electron is accelerated under the influence of the voltage 2E.

Similarly, an electron which enters the electrode **26** at the moment when the electrode **26** has a negative velocity E relatively to the electrode **23** will leave the electrode **27** at a moment when this electrode has a positive velocity E relatively to the electrode **24** with the result that this electron is retarded both on entering and on leaving the control space. In addition, the passage from the electrode **26** to the electrode **27** ensues at a moment when the electrode **26** has a positive voltage 2E relatively to the electrode **27** and on passing from the electrode **26** to the electrode **27** the electron is retarded under the influence of the voltage 2E.

The electrons which enter the control space at the above-mentioned moments are consequently accelerated or retarded respectively in succession on passing from one electrode to the next following under the influence of a voltage E, 2E and E, which has the same effect as though under the influence of a voltage 4E an acceleration or retardation respectively were brought about once.

Owing to this, an electron beam which has passed through the electrode system **24**, **25** will be constituted by electrons having a higher and electrons having a lower speed than the initial speed of the electrons in the beam.

The electrodes **26** and **27** are supplied with control voltages having a relative phase displacement of 180° by inserting an oscillatory circuit between the electrodes **26** and **27** and feeding a control voltage to this circuit. Preferably, the middle point of each of the electrodes is connected to one of the conductors of a Lecher-line system **28** comprising two parallel conductors and whose middle point may be grounded through a high frequency choke coil while its length is so regulated by means of a bridge **29** that the circuit formed by the Lecher conductors and the electrodes **26** and **27** is tuned to the frequency of the control oscillation.

The speed variations are converted into variations in intensity outside the control space in a so-called overtaking or drift space, said space being formed by the space enclosed by the electrode **24**. In this field free space the accelerated electrons after some time will have overtaken the retarded electrons so that in the beam are produced density variations or in fact intensity variations, which latter are dependent on the speed variations present and thus on the amplitude of the control voltage which is supplied in counter phase to the electrodes **26** and **27**.

For the purpose of deriving energy from the beam that is varied in intensity, the electron beam is passed through a space circumscribed by two electrodes **24** and **34** which, internally or externally of the tube **10**, preferably enclose two electrodes **36** and **37**.

The electrodes **36** and **37** are interconnected by an oscillatory circuit **38** which is so proportioned that the circuit formed by the circuit **38** and the electrodes **36** and **37** is tuned to the frequency of the control oscillation or a harmonic thereof. In the given form of construction the oscillatory circuit is formed by a Lecher-line system comprising two conductors whose length can be adjusted by means of a bridge **39** and each of which is connected to the middle point of one of the electrodes **36** and **37** respectively. The electrical middle point of the circuit which is formed by the Lecher-line system and the electrodes **36** and **37** is preferably earthed via a high-frequency choke coil and thus has the same potential as the circumscribing electrodes. On passing through the space bounded by the electrodes **24** and **34**, the groups of electrons of variable density induce an alternating current in the circuit which connects the electrodes **36** and **37** whose frequency corresponds to that of the control voltage supplied to the electrodes **26** and **27**. Due to this oscillations are generated in the oscillator circuit **38** having the same frequency or a harmonic frequency thereof; these oscillations bring about voltages having a phase difference of 180° at the electrodes **36** and **37** and may be supplied to a load circuit. The induction-effect is a maximum if the dimension of the electrodes **36** and **37** in the direction of the beam is such that the transit time of the electrons between two neighboring slits or gaps is half a cycle.

Owing to the symmetrical construction of the electrodes **23**, **26**, **27** and **24** which form the control space and of the electrodes **24**, **36**, **37** and **34** which form the space from which oscillations can be derived, the device according to the invention is particularly suitable for the use of a Lecher-line system comprising two parallel conductors for supplying and deriving energy. Such a Lecher-wire system has the advantage over the use of concentric conductors that leading Lecher wires through the tube wall is easily done.

If desired each of the control electrodes **26** and **27** or **36** and **37** respectively may be connected to the corresponding conductors of two Lecher-line systems diametrically arranged relatively to the control electrodes and in this case the influence of the capacity which the control electrodes form relatively to the surroundings on each of the Lecher-line systems is half that of the capacity in the use of only one Lecher-line system. Such a construction in which each of the electrodes **26** and **27** or **36** and **37** respectively is provided with two diametrically arranged lead-

ing-in wires thus permits of increasing the natural frequency of the oscillatory system of which the electrodes form part.

In the form of construction described the length of the electrodes **26** and **27** was such that the transit time of the electrons along these electrodes is half an oscillation period and in this case the speed modulation obtained ensues under the influence of a voltage **4E** in which E is the maximum amplitude of the control voltages supplied to the electrodes **26** and **27**. The same speed control can be obtained if use is made of a discharge tube in which the electrodes **26** and **27** have half the above-mentioned length or in other words are so long that the spacing between neighboring slits is a quarter of the oscillation period of the control oscillation if the maximum amplitude of the control voltage supplied is **2E**. As a matter of fact, with this choice of the length of the electrodes **36** and **37** an electron that enters the control space at the moment at which there is no potential difference between the electrodes **23** and **26** will pass through the intermediate space between the electrodes **26** and **27** after a quarter of the oscillation period of the control oscillation and at this moment the electrode **27** has either a positive or a negative voltage of **4E** relatively to the electrode **26** so that the electron that entered the control space without being accelerated or retarded is accelerated or retarded respectively on passing from the electrode **26** to the electrode **27** under action of a voltage **4E**. On the control space being left a quarter of the oscillation period later, again an acceleration does not occur, because at this moment there is no voltage drop between the electrodes **27** and **24**.

The electrodes **36** and **37** may be given a corresponding length.

The form of construction in which the length of the electrodes **26** and **27** is such that the transit time of the electrons between neighboring slits is a quarter of the oscillation period of the control oscillation offers the advantage that the capacity which the electrodes **26** and **27** form relatively to each other and to the surroundings is materially lower than in the other form of construction described so that this form of construction permits of obtaining oscillations of higher frequency. In addition, it may be observed that the more the length of the control electrodes increases the greater is the possibility that density variations occur even in the control space with the result that the speed control ensuing at the ends of the control space becomes less effective. Furthermore, it must be borne in mind that the length of the speed control electrode may have any value between the very favorable values indicated in the forms of construction described.

The device according to the invention is not only adapted for amplifying a control oscillation which is supplied in counter phase to the speed control electrodes **26** and **27**; it may also be used for generating oscillations and in this case the circuits **26** and **36** should be coupled together. In addition, the device according to the invention has been found to be highly advantageous for frequency-changing, for example mixing of ultra-high frequency oscillations, and in this case use is preferably made of a device comprising at least two electrode systems for controlling the speed of the electrons, the said systems having respectively supplied to them control voltages of different frequencies.

For generating, amplifying or changing the frequency of oscillations of very high frequency the electrodes **26** and **27** or **36** and **37** respectively are united for example to form a hollow body which is tuned to the frequency of oscillations to be generated, amplified or changed in frequency.

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