Nov. 29, 1966 R. C. HERGENROTHER 3,289,030

ELECTRON TUBE WITH APERTURED INTERDIGITAL DELAY LINE, ADJACENT APERTURES BEING OF DIFFERENT SIZE AND AT DIFFERENT VOLTAGES

Filed April 26, 1963 2 Sheets-Sheet 1

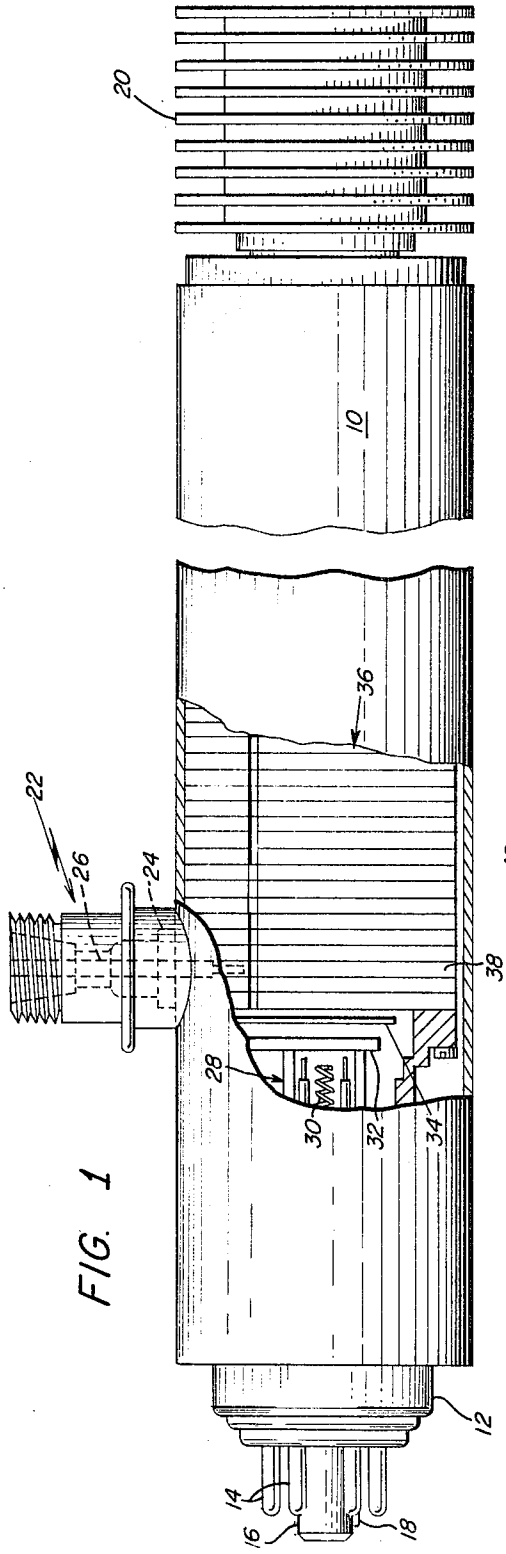


FIG. 1

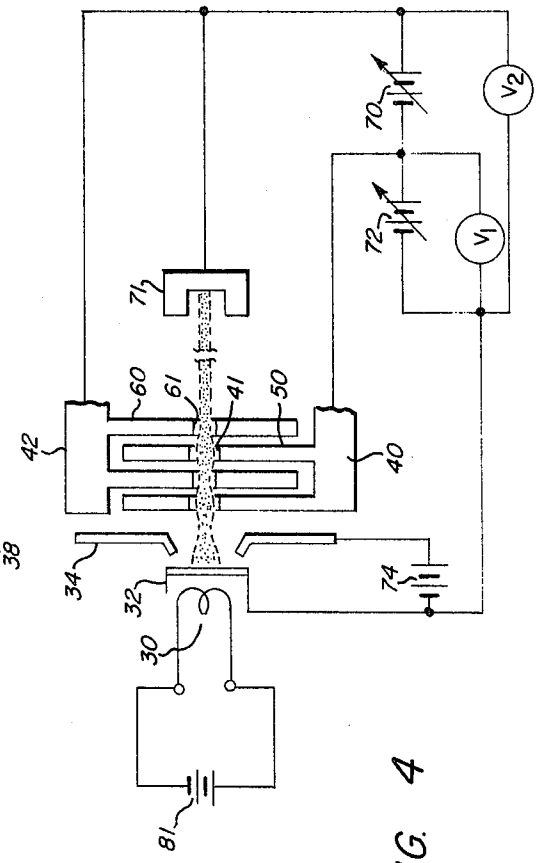


FIG. 4

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FIG. 2

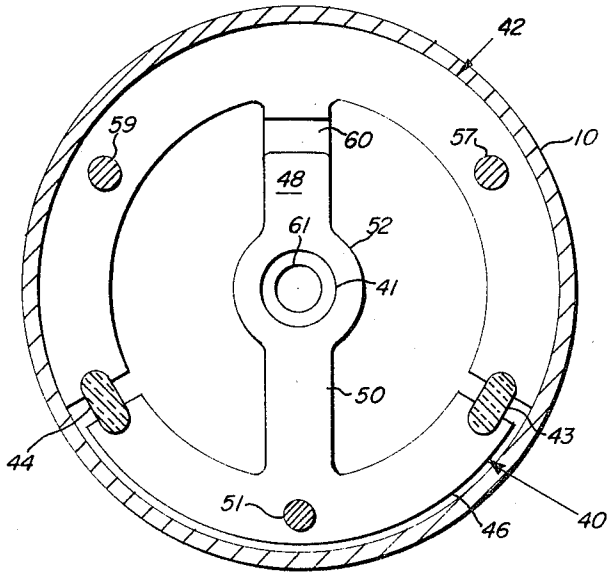


FIG. 3

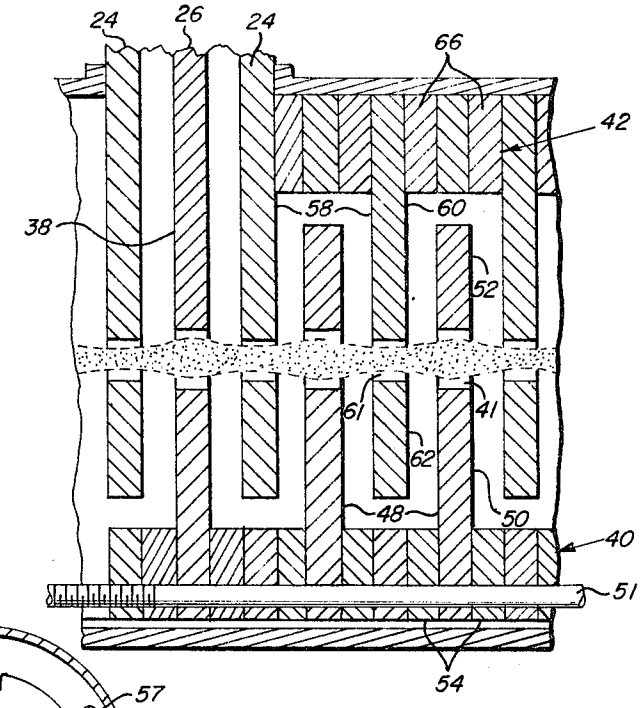
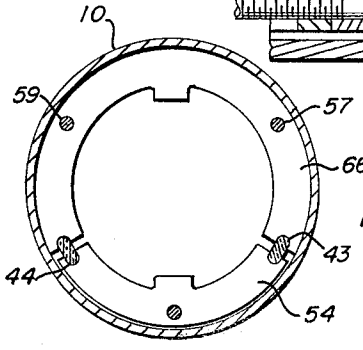


FIG. 5



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ELECTRON TUBE WITH APERTURED INTERDIGITAL DELAY LINE, ADJACENT APERTURES BEING OF DIFFERENT SIZE AND AT DIFFERENT VOLTAGES

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7 Claims. (Cl. 315—3.5)

This invention pertains generally to electron tubes of the traveling wave type, and more particularly to electrostatically focused traveling wave tubes and interdigital delay lines therefor. While the invention is applicable to traveling wave tubes utilizing either forward or backward wave phenomena, the description that follows is directed to backward wave oscillators as being exemplary of other tubes and circuits to which the invention is applicable.

The interdigital delay line, which has a backward wave fundamental mode, has found utility as the delay element in backward wave oscillators and amplifiers. In such electron tubes the electron beam is focused by passing through circular apertures in the delay line interdigitated fingers. The circular apertures are centered on the beam axis of the electron beam. Alternate fingers of the delay line are connected to respective higher and lower potential sources as more specifically described in my co-pending U.S. patent application Serial No. 64,790. In such interdigital electrostatically focused periodic delay lines the circular apertures have equal diameters. As the electron beam passes through successive apertures of uniform diameter but alternately higher and lower potential, the beam tends to alternately expand and contract in diameter because of the well known effect of such higher and lower potentials on an electron particle. This expansion and contraction of the beam produces a "scalloping" effect on the beam and has a detrimental side effect in that unavoidable collisions between the electron beam and the apertured fingers occur predominantly at the lower potential fingers. When the electron beam collides with a finger, secondary emission of electrons from the surface of the finger occurs. These secondary emissions are undesirable in that they enter the electron beam and cause current loading of the delay line tuning circuit, they absorb radio frequency power and they contribute to the generation of spurious oscillations within the delay line structure.

Accordingly, it is an object of the invention to minimize the adverse effect of secondary emission in such delay line structures. To this end, the invention provides a delay line having interdigitated fingers with adjacent apertures of unequal diameter. The aperture diameter of the higher potential fingers is less than the aperture diameter of the lower potential fingers so that collision between the electron beam and the apertured fingers occurs predominantly at the higher potential fingers. The higher potential fingers are at a relatively positive potential with respect to the adjacent lower potential fingers. Secondary electrons are at a much lower velocity than the primary electrons of the electron beam. Consequently, such electrons as are caused to be emitted from the surface of the higher potential fingers by collision of the electron beam with the fingers are more susceptible to the influence of the higher potential electrostatic field and will be effectively suppressed or attracted back to the surface of the higher potential fingers, thereby avoiding the adverse effect of such secondary emissions if allowed to interact with the electron beam as noted in the aforementioned prior art structures.

In accordance with the present invention, the above

and other objects are achieved by means of a traveling wave tube structure including an envelope, a delay line therein having a plurality of interdigitated fingers each having an apertured portion, with such apertured portions being alternately larger and smaller in size and lying in registry with each other and with a beam of electrons produced by an electron gun, means for applying a higher potential to the smaller apertured fingers than to the larger apertured fingers next adjacent thereto to form an electron lens by means of each adjacent pair of fingers, and an output terminal for extracting R.F. energy from the delay line structure.

With the above considerations and objects in mind, the invention itself will now be described in connection with a preferred embodiment thereof given by way of example and not of limitation and with reference to the accompanying drawings, in which:

FIG. 1 is an elevation view of a backward wave oscillator structure in accordance with the present invention, with portions being broken away for clarity;

FIG. 2 is an enlarged transverse vertical section of the structure of FIG. 1;

FIG. 3 is an enlarged sectional view of the structure of FIG. 1;

FIG. 4 is a circuit diagram, including schematic representations of portions of the tube structure, illustrating one manner of applying voltages to certain elements of the structure of the present invention; and

FIG. 5 is a front view of one of the spacer elements of FIG. 3.

Referring now particularly to FIG. 1, a preferred form of backward wave oscillator tube structure in accordance with the present invention is shown as including an envelope **10** having at one end thereof a suitable base **12**, such as a plug member adapted to be inserted in an octal socket, and including a plurality of connecting pins **14** and a central guide member **16** having a key **18** thereon. At the opposite end of the envelope **10** is at suitable finned section **20** which serves as a heat-dissipating means for transferring heat developed within the envelope **10** to the external atmosphere. Envelope **10** also includes an R.F. output terminal **22**, shown as a coaxial connector having an outer conductive member **24** and a central conductor **26**, shown in dotted line in FIG. 1. It will be understood that the coaxial connector **22** is merely exemplary of other suitable output connector means which may be employed in place of the connector **22**.

An electron gun indicated generally at **28** is mounted within envelope **10** near the base **12**, such electron gun including a heater **30**, a cathode **32** and an anode **34**. As is customary, each of the electrodes of the electron gun **28** is connected to one or more of the pins **14** in the connector base **12** in order to be connected to the appropriate points in the circuitry connected to the tube socket into which the base **12** is inserted.

The beam of electrons formed by electron gun **28** is centrally disposed within the envelope **10** and extends from the electron gun **28** toward the right in FIG. 1, passing through the plurality of elements comprising the delay line **36**. While only a portion of delay line **36** is shown in FIG. 1, it will be understood that the stacked elements of the line extend from the electron gun **28** to a position substantially adjacent the opposite end of the envelope **10**, adjacent heat radiator **20**. The electron beam may conveniently comprise a solid cylindrical beam as indicated in FIG. 4, or may take a hollow cylindrical shape as in FIG. 2, or other such shapes dependent on the particular tube configuration desired.

The details of the construction of the delay line **36** will be explained in detail in connection with the descrip-

tion of later figures, but it is convenient at this point to note that the line **36** is composed of a plurality of stacked elements, generally annular in form, and having a plurality of interdigitated fingers forming the electron lenses employed in the present invention for achieving focusing of the electron beam along the length of the envelope **10**. One of the elements **38** making up delay line **36** is conductively connected to the center conductor **26** of coaxial output connector **22**, and by this connection the R.F. energy of a backward wave mode within envelope **10** is conducted from element **38** through central conductor **26** to a suitable external circuit connected to coaxial connector **22**.

FIGS. 2, 3, 4 and 5, taken together, show the structure of delay line **36** in greater detail. In general, delay line **36** is composed of two main portions, a lower portion **40** and an upper portion **42**. The upper portion **42** is in electrical contact with, and mounted on, by means not shown, envelope **10**, while lower portion **40** is mounted on and electrically insulated from portion **42** by means of nonconductive mounting members **43** and **44** which extend lengthwise along delay line **36**. As a result of the slightly smaller outside diameter of the arcuate periphery of portion **40**, this portion of the delay line is insulated from the conductive envelope **10** by means of the semi-cylindrical space **46**.

Delay line portion **40** comprises a plurality of conductive plate-like members **48**, each of which includes a delay line finger **50** having an annular apertured portion **52** therein, as shown in FIG. 2, such plate-like members **48** being held together in stacked, spaced-apart relationship by means of a bolt **51** or the like and a plurality of spacing members **54**. It should be noted that although a "stacked" form of delay line construction is chosen herein as a preferred type of construction, other equivalent structures are within the scope and contemplation of the invention. For example, delay line portions **40** and **42** may be one piece castings rather than the laminations shown herein without departing from the scope of the invention.

The upper portion **42** of delay line **36** is similarly composed of a plurality of plate-like conductive members **58**, each having a delay line finger **60** formed thereon, such fingers **60** lying in substantial registry with fingers **50** and having similarly disposed annular apertured portions **62**. The apertures **61** in fingers **60**, however, unlike prior art structures, are smaller than the corresponding apertures **41** in adjacent fingers **50**. Fingers **50** are connected to a source of lower potential than the potential on fingers **60** as will be subsequently shown in connection with FIG. 4. The plate-like members **58** of delay line portion **42** are similarly held together in stacked, spaced-apart relationship by means of bolts **59** and **57** or the like, along with a plurality of spacer members **66**.

In operation, it should be noted that the resultant electron beam passing through apertured fingers **50** and **60** takes the form of a "scalloped" shape beam alternately increasing and decreasing in diameter in accordance with the respective alternately lower and higher potentials impressed across the apertures. Furthermore, as can be seen from FIG. 3, collision between the beam and the apertured fingers will occur predominantly at the higher potential, smaller diametered apertures **61** in fingers **60**. Conversely, very few collisions will occur at the lower potential fingers **50**. This scalloping effect is exactly opposite to that produced in prior art structures wherein the majority of collisions occur at the lower potential fingers in uniformly apertured delay line structures. Accordingly, in the delay line device of the invention, secondary emission caused by such collisions occurs predominantly on the higher potential fingers **60**. Such secondary emissions as do occur are effectively suppressed or attracted back to the surface of the higher potential fingers by virtue of such higher potential.

Referring now to FIG. 4, an exemplary circuit is shown therein for applying appropriate voltages to the active elements of the backward wave oscillator structure of the prior figures. In FIG. 4, the delay line voltages are supplied by D.C. sources **70** and **72**, indicated schematically as batteries in FIG. 4. The positive terminal of source **70** is connected to the upper delay line portion **42**, having the smaller diameter apertures **61** therein, as well as to collector element **71**. The negative terminal of source **70** is connected to the lower delay line portion **40** having the larger diameter apertures **41**. This lower portion **40** is also connected to the positive terminal of D.C. source **72**, the negative terminal of such source being connected to cathode **32**. It will be understood that sources **70** and **72** are preferably made variable in order to provide means for effecting variable tuning and focusing of the electron tube. A third D.C. source **74** is connected between cathode **32** and anode **34**, with its positive terminal being connected to anode **34** and its negative terminal being connected to cathode **32**. A fourth source **81** supplies voltage to heater **30**. By virtue of this circuitry a first D.C. potential designated generally as V_1 is established between cathode **32** and delay line portion **40**, with a second and greater D.C. potential designated generally as V_2 being established between cathode **32** and delay line portion **42**. The effective delay line voltage V is equal to the average of these two voltages V_1 and V_2, that is to say

$$V=\frac{V_1+V_2}{2}$$

The operation of the apparatus described herein is similar in most respects to the operation of other backward wave mode structures, except that by virtue of the particular construction of the interdigital delay line **36**, and the application of the different D.C. voltages to the two portions **40** and **42** thereof, the necessity for supplying a magnetic focusing means is obviated, since focusing of the electron beam **76** is achieved electrostatically by means of the electron lenses formed between each adjacent pair of delay line fingers **50** and **60**. With the beam thus focused along its length within the envelope **10**, a backward wave mode is produced within the structure, and R.F. energy is extracted from the structure through coaxial connector **22** for use in an external circuit.

Heretofore, in delay line structures of the type described in reference to FIGS. 1–4, secondary emission of electrons caused by collision between the electron beam and the apertured interdigitized fingers **40** and **42** took place predominantly on the lower potential fingers **50**. In the present invention, however, by virtue of the unequally apertured fingers, substantially all of the beam collisions will occur at the higher potential fingers **60** where the secondary electrons produced by collision of the primary or beam electrons can be effectively suppressed and drawn back to the high potential fingers thereby reducing the adverse effects of secondary emission on the delay line structure. Such adverse effects include, among others, current loading of the delay line tuning circuit, loss of R.F. power by absorption from secondary electrons and spurious oscillations within the delay line structure.

The invention has been described above in some detail, and particularly with reference to its application to backward wave oscillators. However, it will be apparent to those skilled in the art that the invention is also applicable to other structures employing an interdigital delay line, and in particular to other traveling wave devices. Accordingly, it is desired that this invention not be limited except as defined by the appended claims.

What is claimed is:

1. In a delay line structure:

a plurality of interdigitated members having alternately smaller and larger apertures therein;

and voltage means coupled to alternate interdigitated

members such that the interdigitated members having the smaller apertures are at a higher potential than the interdigitated larger apertured members.

2. In combination:
envelope means;
a plurality of interdigitated apertured members disposed within said envelope, the size of the apertures in said interdigitated members being alternately larger and smaller;
means for directing a beam of electrons past said apertured members;
and means for applying a higher potential to the smaller apertured members and a lower potential to the larger apertured members.

3. Delay line means for focusing an electron beam comprising:
interlaced alternate and intermediate finger means, each of said finger means having an aperture therein located substantially at the beam axis of said electron beam, alternate finger means being coupled to a relatively higher potential source than said intermediate finger means, the size of the apertures being relatively smaller for the alternate finger means than the size of the apertures of the intermediate finger means so that collision between the electron beam and the delay line means occurs predominantly at the higher potential finger means thereby to prevent secondary emissions from entering the electron beam.

4. In combination:
envelope means;
an interdigital delay line within said envelope having a plurality of fingers each including an apertured portion, each of said apertured portions being in substantial alignment with one another, the size of the aperture in each finger being different than the size of the aperture in the finger next adjacent thereto;
means for applying to each of said fingers a voltage different from that applied to the fingers next adjacent thereto;
means for directing a beam of electrons past the aligned apertures of said fingers;
and means for extracting energy from said delay line.

5. In combination:
envelope means;
an interdigital delay line within said envelope having a plurality of fingers each including an apertured portion, each of said apertured portions being in substantial alignment with one another, the size of the aperture in each finger being different than the size of the aperture in the finger next adjacent thereto;
means for providing a higher potential to the smaller of said different sized apertures than that applied to the larger of said different sized apertures;
means for directing a beam of electrons past the aligned apertures of said fingers;
and means for extracting energy from said delay line.

6. In combination:
delay line means for focusing an electron beam comprising interlaced alternate and intermediate finger means, each of said finger means having an aperture therein located substantially at the beam axis of said electron beam, alternate finger means being coupled to a relatively higher potential source than said intermediate finger means, the size of the apertures being relatively smaller for the alternate finger means than the size of the apertures of the intermediate finger means so that collision between the electron beam and the delay line means occurs predominantly at the higher potential finger means thereby to prevent secondary emissions from entering the electron beam;
electron gun means for providing said electron beam and directing said beam past said interlaced fingers means;
potential source means for providing a first relatively high potential and a second relatively lower potential;
envelope means enclosing said delay line means and said electron gun means;
and means coupled to said delay line means for extracting energy from said delay line means.

7. A traveling wave electron discharge device having a plurality of interdigitated apertured members, the size of the apertures in said members being alternately larger and smaller, means for directing a beam of electrons past said apertured members, and means for applying a first potential to the smaller apertured members and a second potential to the larger apertured members, said first potential being greater than said second potential.

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