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GRIDDED ION-DRAIN ELECTRODE STRUCTURE
FOR TRAVELING WAVE DEVICES

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2 Sheets-Sheet 1

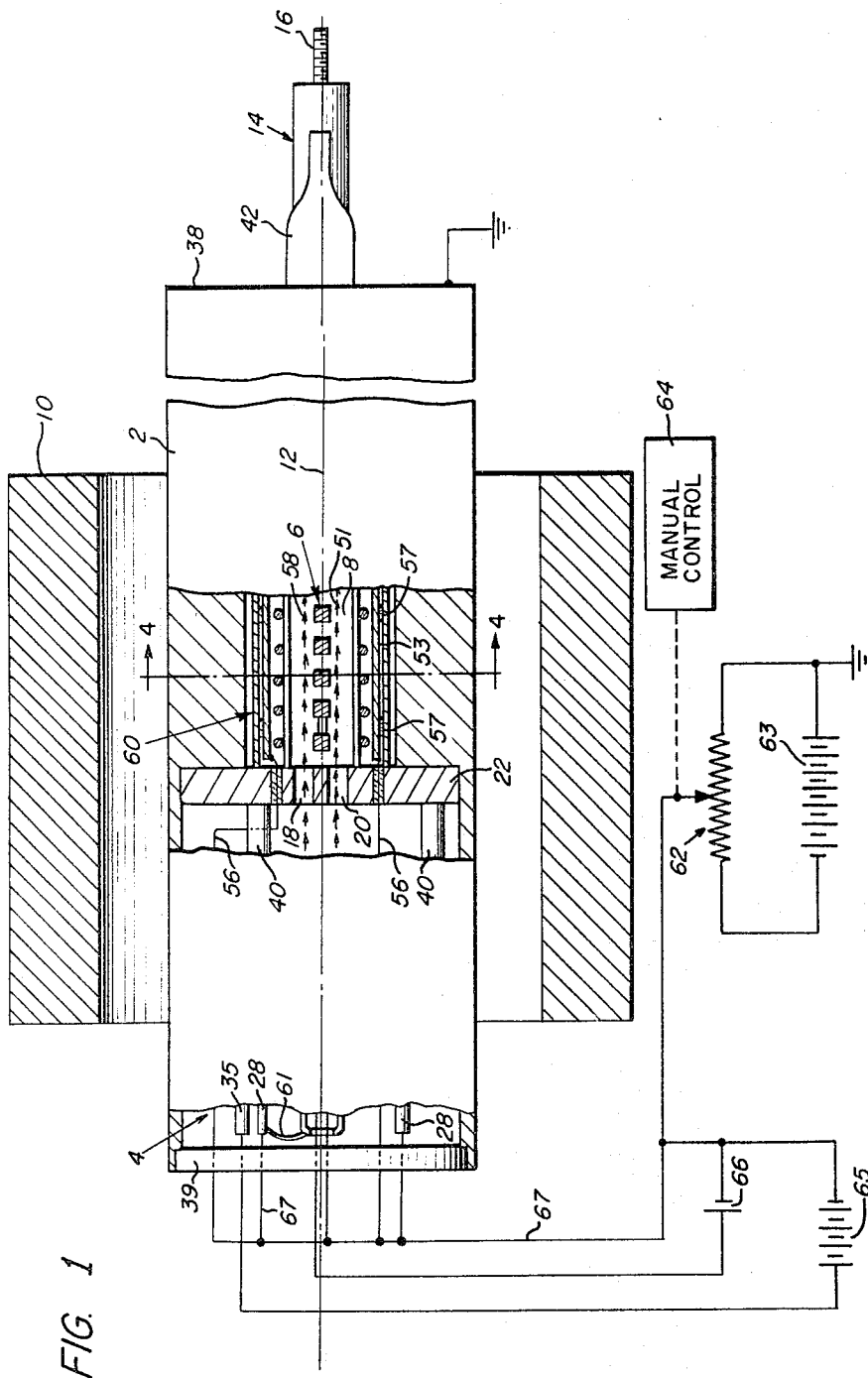


FIG. 1

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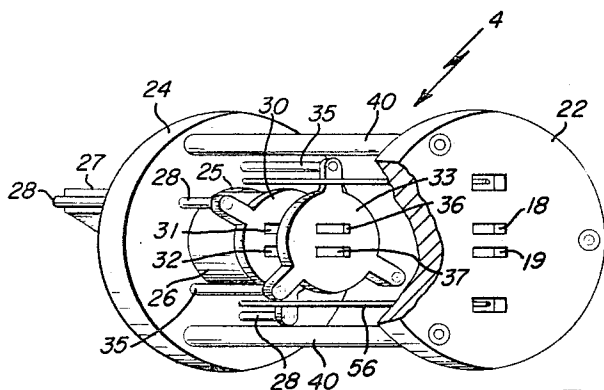


FIG. 2

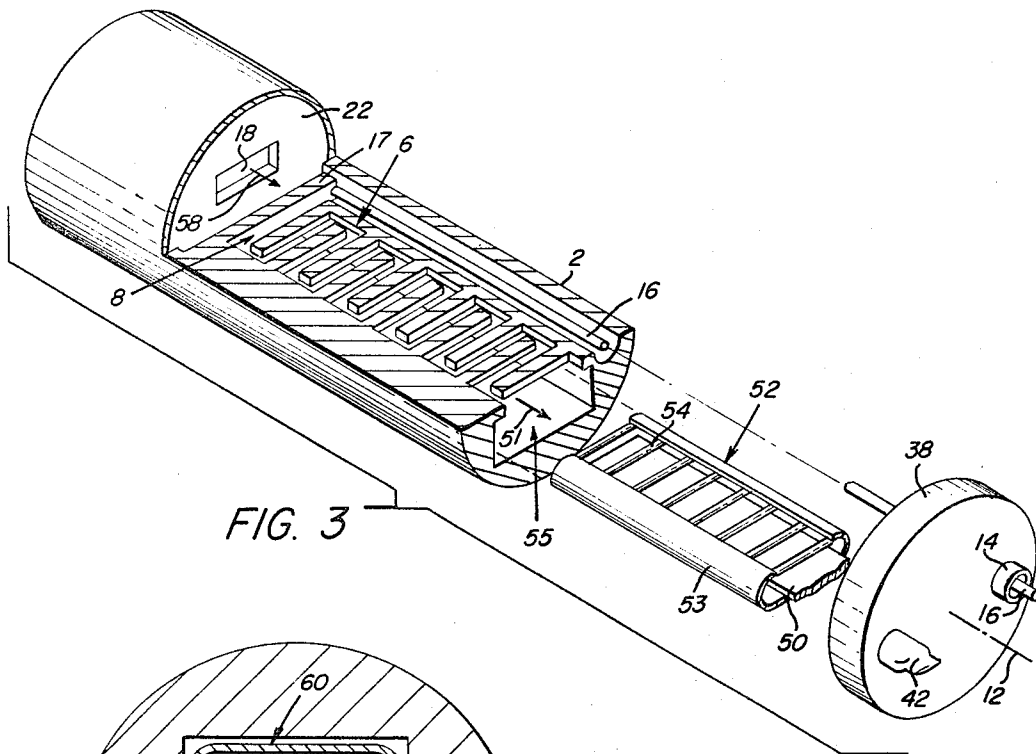


FIG. 3

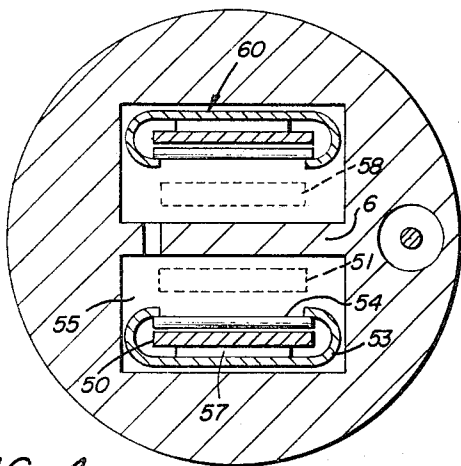


FIG. 4

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GRIDDED ION-DRAIN ELECTRODE STRUCTURE FOR TRAVELING WAVE DEVICES

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3 Claims. (Cl. 315—3.5)

ABSTRACT OF THE DISCLOSURE

A gridded ion trapping electrode spaced adjacent to the delay line structure of a backward wave type traveling wave-electron beam interaction device to substantially reduce spurious frequency modulations caused by plasma oscillations of the positive ions which are produced by the electron collisions.

The present invention relates generally to electron discharge devices of the traveling wave type, and more particularly to an improved electrode structure for optimizing performance of such devices employing an electron beam.

Traveling wave electron discharge devices of the backward wave type commonly provide an extended electron beam within an evacuated envelope caused to interact with the electromagnetic field of a wave propagating along a periodic slow-wave structure, such as for example, an interdigital delay line. The electron beam is focused along the predetermined path adjacent to the slow-wave structure by longitudinal magnetic means. When the electron beam velocity is in substantial synchronism with the velocity of one of the negative space harmonics referred to as backward waves generated in the periodic slow-wave structure, oscillations may be generated within the device. These oscillations will propagate along the periodic structure and may be extracted by means of a coaxial output transmission line coupled to a member of the periodic structure. Such backward wave oscillators with all the operating parameters optimized have nevertheless displayed a phenomenon termed in the art as "quiescent frequency modulation" or "QFM" which results in undesirable spurious oscillations.

Among the contributing factors to this phenomenon of QFM as noted by many leading research scientists in the art are as follows:

(1) Plasma oscillations of the positive ions which are attracted by the space charge of the electron beam and which are triggered by the secondary electrons; and

(2) Relaxation oscillations caused by the space charge neutralization due to the ions produced by the electron collisions.

It may be noted that in each of the aforementioned factors, positive ions reacted upon by the beam in the interaction space are involved, and such ions move much more slowly than electrons. Good vacuum technology in the fabrication of the devices as well as "white-room" production facilities will contribute to a reduction in the number of residual gas molecules within such devices which produce positive ions by collision of moving electrons. To further reduce the number of such ions, the present invention discloses a shielded ion-draining electrode disposed in close proximity to the focused electron beam. Such structure has contributed greatly to the reduction of the QFM spurious oscillations and has improved tube output performance. While the use of positive ion-trapping or draining electrodes has been attempted in the prior art, the placement of such electrodes in proximity to the electron beam as well as the requirement for an additional source of potential has created

certain inherent problems not heretofore experienced in backward wave oscillator devices. Due to the placement of such an electrode in relation to the interaction space and the application of a source of higher negative potential with relation to a periodic wave structure, the resultant electron beam has been adversely affected with a resultant drop in output. Removal of such a draining electrode further away from the electron beam has not been reliable and has not eliminated the necessity for the provision of an additional connection to an external voltage source.

It is, therefore, a primary object of the present invention to provide an improved positive ion-draining electrode for traveling wave electron discharge devices.

Another object of the present invention is the provision of an improved positive ion-draining electrode capable of reducing quiescent frequency modulation without requiring an additional external voltage biasing connection.

Still another object of the present invention is the provision of an improved positive ion-draining electrode for traveling wave electron discharge devices which avoids the disadvantages of prior art structure.

Other objects, features and advantages will be evident after consideration of the following detailed specification and the accompanying drawings in which:

FIG. 1 depicts one embodiment of the present invention showing a partial cross-sectional view of a traveling wave type backward wave oscillator;

FIG. 2 shows an exaggerated perspective view of the electron cathode gun assembly of said device;

FIG. 3 is an exploded three-quarter cutaway view illustrative of the placement of the improved electrode structure with relation to an interdigital delay line; and

FIG. 4 is a longitudinal cross-sectional view along the line 4—4 in FIG. 1.

Referring to FIG. 1, there is shown a traveling wave electron discharge device of the backward wave oscillator type comprising a cylindrical envelope 2 enclosing an electron cathode gun structure 4 and an interdigital slow-wave delay line structure 6 disposed within cavity 8. A cylindrical magnet 10, concentric with the cylindrical body 2, provides a magnetic field which is substantially uniform at the center of the body and parallel with the body axis 12.

The electron cathode gun structure 4 generates a plurality of strip electron beams which pass through rectangular openings 13 and 20 in plate 22 enclosing one end of the delay line cavity 8. While the illustrative embodiment is described with relation to plural electron beams, the invention will be equally applicable to electron discharge devices having only a single electron beam.

With reference now to FIG. 2, there is shown a perspective view of the cathode structure 4 disposed at one end of the tube envelope for the generation of the electron beam. This structure comprises a ceramic plate 24 having a circular opening 25 at its center through which a cathode cylinder 26 is mounted. The cylinder is held in place by metal strips 27 fastened to cylinder 26 and elongated pins 28 which extend through apertures in ceramic plate 24 and are held held firmly thereby. The inner end of pins 28 engage and support a cathode plate member 30 defining a plurality of rectangular openings 31 and 32 to form the electron beams issuing from a cathode emitter of conventional configuration contained within the cathode cylinder 26. Such an emitter commonly comprises an electron emissive body with a filament for directly heating same.

Focusing member 33 is positioned parallel to the cathode plate 30 by means of pins 35 extending axially through and supported by ceramic plate 24. Rectangular openings 36 and 37 are in axial alignment with openings 31 and 32 and form the boundaries of an electrostatic

field for acceleration of the electrons as a consequence of voltage biasing to be hereinafter described.

Plate member 22 defining openings 18 and 20 is supported by ceramic plate 24 by means of posts 40. The overall device is provided with an end plate 39 through which the external leads to the cathode gun structure members extend and is hermetically-sealed to the envelope 2. The opposing end is provided with a cover member 38, and the device is evacuated by means of exhaust tube 42 which is tipped off and sealed after the desired reduced atmosphere or vacuum is attained.

In accordance with the teachings of the invention, reference now being directed to FIGS. 3 and 4, positive ion-draining electrode 50 is provided having a configuration substantially matching that of the rectangular strip beam adjacent thereto and indicated by the arrow 51. The enlarged width of the electrode will facilitate more uniform ion drainage in the region adjacent to the beam. The electrode 50 is enclosed and screened by a grid member 52 comprising a backing member 53 and grid elements 54 disposed parallel to the disposition of the fingers in delay line 6. The entire gridded ion-draining electrode structure is assembled within a channel 55 defined in the tube envelope 2 immediately adjacent to the path of the electron beam. Provision of the grid shield has been successfully tested with the ion-draining electrode biased at the envelope, anode or cathode potentials. In the illustrative embodiment, a connection by means of lead 56 is shown to bias the electrode 50 at the same potential as the cathode member 26. In such applications with the electrode connected to the existing cathode potential source, ceramic spacers 57 are employed in order that the grid members 53 and 54 will be electrically isolated with respect to electrode 50 and in no way affect the beam focusing of the electron stream.

It is understood in the practice of this invention that the ion-drain electrode may be internally connected to any other existing potential source with suitable modifications. In addition, in plural electron beam devices a similar assembly of an ion-drain electrode and enclosing grid screen will be provided adjacent to the beam traversing the other side of the delay line 6. Such a beam is emitted through the opening 18 in plate 22 and is indicated by the arrow 58. Referring again to FIG. 1, a similar gridded ion-draining electrode assembly is positioned immediately adjacent to the electron stream and is indicated generally by the numeral 60. This structure is similar to the opposing electrode assembly, and similar components are similarly numbered.

The use of ion-draining electrodes consisting primarily of a wire operated at an individual negative potential with respect to the interdigital delay line structure has been suggested in the art. Such structure, however, has met with the requirement for an additional source of potential since it was impossible to connect such electrodes to existing voltage supplies without having a serious effect on the tube performance as a result of distortion of the electron beam configuration. Numerous experimenters have attempted to remove such wire electrodes structures to slots or channels immediately adjacent to the electron stream. It was noted, however, that any ion drainage was sporadic at most and was essentially oriented at only the center of the beam which resulted in little or no effect in the suppression of quiescent frequency modulation. The present invention has overcome the prior art disadvantages in that the provision of a gridded member which is electrically connected to the delay line potential, immediately adjacent to the ion-drain electrode, permits the exposure of the entire surface of the draining electrode to trap the positive ions which are disposed in the area traversed by the electron beam. This gridded structure has facilitated placement of the ion-drain electrode in closer proximity to the beam area and has reduced the intensity of the electric field in this area so that the beam focusing will not be adversely af-

ected. Such shielding has further provided a means for the matching of the electric field generated by the ion-drain electrode to any selected interdigital delay line structure by adjustment of the grid dimensions. As noted previously, such grid screening has further enabled such electrode structures to be employed without the necessity for providing additional voltage potential sources. Employment of the structure disclosed herein with the grid design optimized to provide maximum ion draining with no adverse effect on beam focusing, in fact, assisted such focusing and improved the overall output of the device.

In operation as a backward wave oscillator, the illustrative embodiment is coupled to external voltage biasing sources in the following manner: The cathode emitter and cathode cylinder 26, as well as plate member 30, are electrically coupled together by means of a conductive ribbon 61, and all are coupled to the arm of a potentiometer 62. The other terminals of the potentiometer are connected across a voltage source 63 with the positive terminal grounded. By means of manual control 64, a variable negative voltage is applied to the emitter, cathode cylinder and cathode plate. Plate member 33 may be placed at a slightly more positive bias than the adjacent cathode plate 30 to assist in the acceleration and focusing of the electron beam. The negative terminal of battery 65 is coupled to the arm of potentiometer 62, and the positive terminal of the battery 65 is coupled to the support pin 35 for plate 33. A low voltage battery 66 supplies energy for the cathode heater contained within cathode cylinder 26. The gridded ion-draining electrode structure in accordance with the practice of the invention may be connected by leads 56 to leads 67 extending from the highly negative voltage source 63.

The electrons emitted from the cathode gun traverse the beam forming members 30 and 33 and are accelerated by the electrostatic fields between the respective plates disposed in the electron path. Since the magnetic field provided by the magnet 10 is substantially parallel to the electron beam direction, the electrons are focused in the interaction space adjacent to the interdigital delay line 6. The interaction of the beam of electrons with the electric and magnetic field disposed on the periodic slow-wave structure results in the generation of electromagnetic energy. This energy is coupled through the inner conductor 16 from the interdigital delay line finger 17 positioned close to the plate member 22. The oscillator output is then coupled to external circuitry by means of coaxial transmission lines coupled to the inner conductor 16 and outer conductor 14.

While a specific embodiment of the present invention has been illustrated and described, it will become apparent to those skilled in the art that the novel structure disclosed herein may be incorporated in other types of traveling wave electron discharge devices providing an interaction space adjacent to a slow-wave structure for the traversing of an elongated electron beam. Such devices include the circular delay line configuration of the so-called M-type forward wave or backward wave oscillators and/or amplifiers or linear magnetrons. The invention is also not to be limited to the particular periodic structures shown and is equally applicable to ladder lines, bar lines, or other delay line configurations by merely modifying the grid dimensions to provide the desired shielding of the drain electrode with respect to the electron beam.

What is claimed is:

1. An electron discharge device of the traveling wave type comprising:
 - a) an evacuated envelope;
 - b) a periodic delay line for propagating electromagnetic energy disposed within said envelope;
 - c) said delay line producing in a path adjacent thereto a radio frequency electric field of the electromagnetic energy being transmitted;

means for producing and directing an electron beam along said path;
 means for producing a magnetic field parallel to said electron beam;
 means for draining positive gas ions produced by collision of the electrons in said beam with residual gas molecules in said envelope;
 said means comprising an electrode having a configuration substantially matching that of the electron beam disposed coextensive with and adjacent to said beam;
 means electrically connecting said electrode to said beam producing means;
 a plurality of conductive elements disposed intermediately to said electrode and electron beam path;
 said elements being electrically isolated from said electrode and spaced apart a sufficient distance to provide a means for matching the electric field generated by said electrode to the electric field generated adjacent to said delay line.
 2. A traveling wave tube comprising:
 an evacuated envelope;
 means defining an interdigital delay line disposed along the longitudinal axis of said envelope for propagation of electromagnetic energy;
 said delay line defining an extended interaction region adjacent thereto bounded by a radio frequency electric field of the electromagnetic energy being transmitted with the lines of force of said field extending perpendicular to the longitudinal axis of said envelope;
 means for producing a magnetic field extending parallel with the longitudinal axis of said envelope;

emissive means disposed adjacent to one end of said delay line for producing and directing a substantially parallel electron beam throughout the length of said interaction region;
 electrically conductive means disposed coextensive with and in close proximity to the radio frequency electric field boundary;
 said conductive means being negatively biased with respect to said delay line electric field to attract positive gas ions produced by collision of the electrons in said beam with residual gas molecules in said envelope;
 an elongated grid member having a plurality of spaced metallic elements disposed along the boundary limitation of the radio frequency electric field;
 said grid member being electrically isolated from said conductive means and the spacing of the metallic elements being selected to reduce the effect of the electric field of said conductive means on the electric field generated along said interaction region.
 3. A traveling wave tube according to claim 2 wherein the grid member defines a plurality of parallel metallic elements disposed transversely to the longitudinal axis of said envelope.

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