Feb. 10, 1948. P. L. HARTMAN 2,435,586

ELECTRON VELOCITY SORTING DISCHARGE DEVICE

Original Filed Dec. 20, 1941 2 Sheets-Sheet 1

FIG. 1

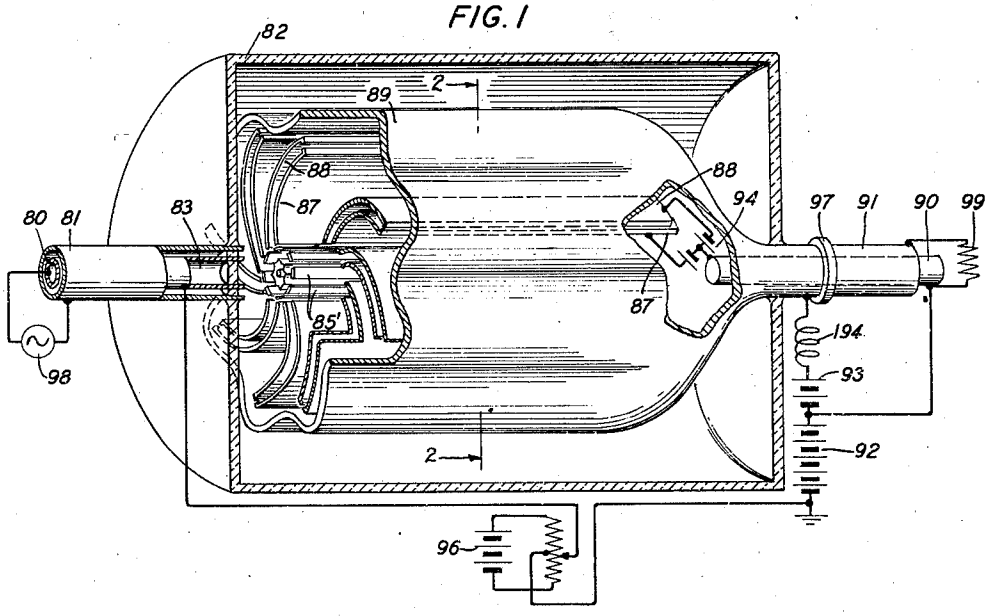

FIG. 3

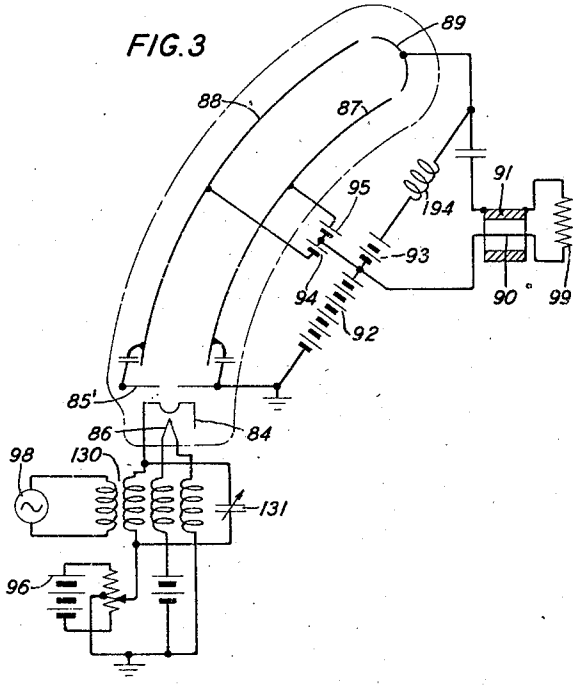

FIG. 2

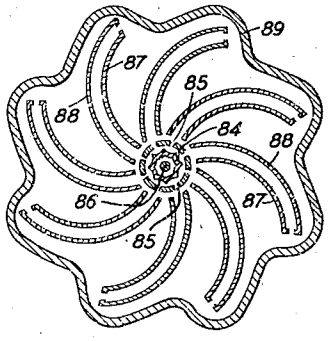

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FIG. 4

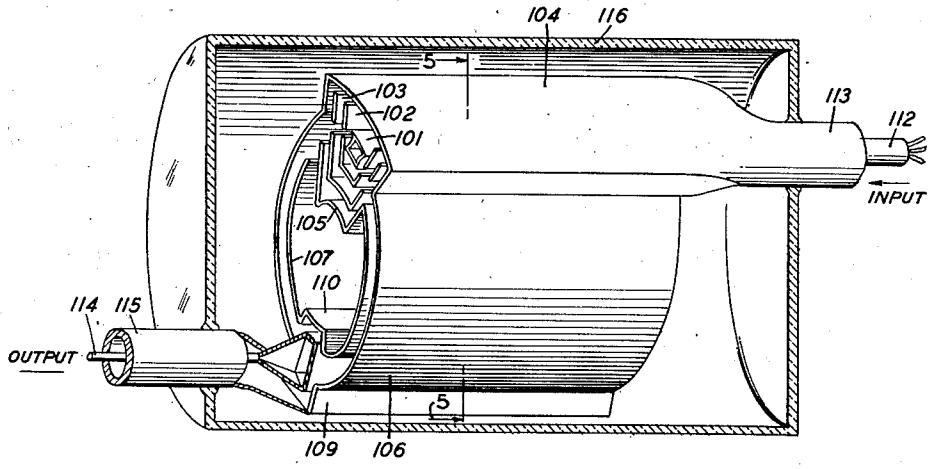
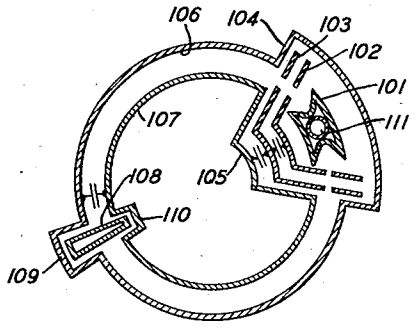


FIG. 5



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2,435,586

ELECTRON VELOCITY SORTING DISCHARGE DEVICE

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Original application December 20, 1941, Serial No. 423,788. Divided and this application December 30, 1943, Serial No. 516,290

2 Claims. (Cl. 315—39)

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This invention relates to systems employing electron discharge devices and particularly to the design and operation of such systems for use at ultra-high frequencies.

An object of the invention is to extend to still higher frequencies the usefulness of electron discharge devices designed for high frequency operation by using specially adapted electrodes, connecting circuits and modes of operation.

A feature of the invention is the use of coaxial electrodes and transmission lines for input and output connections of the electron discharge device in a number of arrangements particularly adapted for operation in a wide range of frequencies including the centimeter wave length range.

Another feature is the use of a reflecting or retarding potential to effect a process of velocity sorting of the electrons in a velocity varied electron stream.

This application is a division of my copending application, Serial No. 423,788, filed December 20, 1941.

Other objects and features are brought out in the following description with reference to the accompanying drawings, while the scope of the invention is defined in the appended claims.

In the drawings:

Fig. 1 is a perspective view, partly broken away, of an embodiment of the invention

Fig. 2 is a cross-sectional view of a portion of the structure of Fig. 1;

Fig. 3 is a schematic diagram of circuit connections for the arrangement of Figs. 1 and 2;

Fig. 4 is a perspective view, partly broken away, of another embodiment of the invention; and

Fig. 5 is a cross-sectional view of a portion of the structure of Fig. 4.

Fig. 1 shows an arrangement operating on the principle of electron velocity sorting or filtering, and suitable for insertion between tuned coaxial transmission lines. An input section of line with an inner conductor 80 and an outer conductor 81 is shown entering an insulating evacuated envelope 82 through suitable seals. The inner conductor 80 is preferably hollow, at least at the end within the envelope and merges into a fluted cathode 84 shown more clearly by cross-section in Fig. 2. A section of the outer conductor 81 within the envelope and opposite cathode 84 is provided with a plurality of axial slots 85, one opposite the center of each concave portion of the cathode. An insulated heating element 86 is supported in an axial position within the cathode 84 in any suitable manner and the ends of the

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element 86 are brought out through the conductors 80, 81 and through the envelope 82 in any suitable manner, not shown, the connections to the element 86 being insulated from the conductors 80, 81.

Opposite each of the slots 85 is suitably mounted a pair of curved substantially parallel plates 87, 88 which may be of circular cylindrical shape and preferably have a mean circular arc of approximately 127 degrees.

The assembly of plates 87, 88 is enclosed in a hollow conductive corrugated tube 89, as shown, the outer opening between each individual pair of plates 87, 88 being close to one of the corrugations in the tube 89.

At the end of the envelope 82 opposite the input transmission line 80, 81 there is sealed an output coaxial transmission line with inner conductor 90 and outer conductor 91. The inner conductor 90 terminates inside the envelope 92 where it is conductively connected to the assembly comprising the plurality of plates 87, 88 through biasing means as hereinafter more fully described. The outer conductor 91 flares to merge with the tube 89 but is insulated therefrom by a suitable coupling section 97.

In the operation of the system of Figs. 1 and 2 the element 86, when heated, serves to heat the cathode 84 and by virtue of the shape of the fluted surface of the cathode 84 a sheet of electrons is emitted and focused to pass through the slot 85, there being a sheet of electrons for each slot 85.

The operation of the various elements of the tube will be more readily understood from Fig. 3 which is a schematic diagram including the connecting circuits. The anode element 89 is p'aced at a relatively high positive potential with respect to the cathode 84 by means of the combined voltage of batteries 92, 93 and 96 preferably through an inductive element 194, which latter, at ultra-high frequencies, may comprise merely the inductance of a short length of conductor. The plates 87, 88 are biased to slightly different potentials with respect to the junction point between the batteries 92 and 93 by means of batteries 94 and 95, respectively, or by other suitable means. The potential difference between the cathode 84 and a grid 85' is adjusted to a small positive or negative value by means of a potentiometer across the battery 96. It will be understood that any or all of the batteries shown may be replaced by any other suitable sources of direct electromotive force. Electrodes 85, 87 and 83 are preferably connected together for

high frequencies by means of built-in by-pass condensers.

A high frequency wave to be amplified may be impressed upon the input transmision line 80, 81 by a suitable source 98 and the output transmission line may be connected with a load represented by a resistor 99. The input line and the associated cathode and heater leads are represented in Fig. 3 by an equivalent transformer 130 tuned by a condenser 131. The source 98 will set up a pulsating potential difference between the cathode 84 and the grid 85' thereby impressing a succession of velocity variations upon the electrons in the stream emerging from the cathode. Depending upon the fixed potential difference between the plates 87 and 88 the electrons will follow various curved paths in the space between the plates under the influence of the transverse electric field therebetween. Within a certain narrow range of velocities all the electrons entering the space between the plates with such velocities will emerge at the far end without striking either of the plates and be drawn to the anode 89. Electrons having velocities below the critical range will strike the plate 87 and electrons having velocities greater will strike the plate 88. Hence, if the system is adjusted so that the potential differences impressed by the input waves are such as to vary the electron velocities through the critical range, the electron current to the anode 89 will be varied, thereby generating a high frequency current in the output circuit. It will be evident that the high frequency component of the output current will be transmitted to the load 99 through the output transmission line 90, 91.

The system may be adjusted for operation either as an amplifier, an oscillator, a detector, or a frequency doubler. By adjusting the potentials of the several electrodes either so that substantially no electrons or substantially all the electrons reach the anode 89 in the absence of any high frequency excitation the system acts as a detector, responding to changes in the amplitude of an impressed high frequency wave. When using the system as a detector the output circuit may be tuned to the input frequency to take advantage of regenerative amplification and the detected output may be received in any suitable device incorporated in the load 99.

Amplification is secured when the potentials of the several electrodes are adjusted to reduce the current, preferably to half of its maximum value, in the absence of excitation. With an amplifying adjustment, the impressed high frequency wave will cause fluctuations above and below the initial anode current value to produce a replica of the impressed wave in the anode circuit.

It will be evident also that the system may be adjusted to give either one or two output pulses for each cycle of the input wave, thereby giving either amplification or frequency doubling, the latter adjustment being similar to the adjustment for a detector.

An alternative arrangement operating on the same principle as the system of Figs. 1, 2 and 3 is shown in Figs. 4 and 5. The arrangement of the elements is seen most readily by cross-section in Fig. 5. The cathode 101 has but two active surfaces both of which are fluted as are the surfaces of the cathode 84 in Fig. 2. A pair of focusing electrodes 102 and 103 are provided between the cathode 101 and enlargements 104 and 105 respectively, of a pair of concentric cylinders

106 and 107. The non-enlarged portions of the cylinders 106, 107 form a pair of arcuate velocity filtering elements, one on either side of the cathode 101. The arc subtended by each filtering element is again preferably approximately 127 degrees. A common anode 108 is provided enclosed by enlargements 109 and 110 respectively, of the cylinders 106 and 107. A heating element 111 is provided within the hollow interior of the cathode 101, the ends of the element 111 being suitably brought out through a hollow inner conductor 112 forming part of an input coaxial line, shown at the right of Fig. 4, and having an outer conductor 113. The inner conductor 112 is conductively connected to the cathode 101. The outer conductor 113 flares to merge into the enlargement 104. The anode 108 merges with the inner conductor 114 of an output coaxial line of which the outer conductor 115 is flared to merge with the enlargement 109. Any suitable means may be provided to support the coaxial lines and the various electrodes and the assembly may be suitably enclosed by a vacuum-tight insulating envelope 116, the latter serving incidentally as a support. For example, the outer conductor 113, enlargement 104, cylinder 106, enlargement 109 and outer conductor 115 may be integral and supported by the envelope surrounding the conductor 115 at the left and the conductor 113 at the right. The cathode 101, electrodes 102 and 103, and cylinder 107 may be supported by the conductor 112 properly sealed into the envelope, and the leads from the heater 111 and from the other electrodes comprising members 101, 102, 103, 107 may be brought out through the hollow interior of conductor 112. The anode 108 may be supported by the conductor 114 properly sealed into the envelope. Built-in by-pass condensers are preferably provided connecting elements 102, 103, 105, 106 and 107 together for high frequencies.

In the operation of the system of Figs. 4 and 5, with suitable biasing potentials applied, a sheet of electrons emerges from either side of the cathode 101, passes through the slots in the focusing electrodes 102 and 103, and enters the space between the cylinders 106 and 107. In the critical range of electron velocities the sheet of electrons reaches the anode 108. At other electron velocities the electrons are intercepted by one or the other of the cylinders 106 and 107, as described in connection with Fig. 3.

What is claimed is:

1. A space discharge device comprising inner and outer hollow coaxial cylindrical conductors insulated from each other, said outer conductor constituting an anode and said inner conductor constituting a grid and having a plurality of axially extending slots therein, a plurality of velocity filters for electrically charged particles, each of said filters comprising a pair of curved spaced substantially parallel conductive plates disposed between said anode and said grid and having two pairs of axially extending ends, each pair providing an opening to the space between said plates; said openings being for input and output of charged particles respectively, the input opening of each filter being aligned with a respective slot in said grid structure and the corresponding output opening being in proximity to said anode, a cathode mounted axially within said grid, means coupled to said anode for supplying a potential with respect to said cathode, and means coupled to said plates for biasing one respective plate of each said filter at one poten-

tial with respect to said cathode and the other respective plate in each filter at another slightly different potential with respect to said cathode, said two potentials being intermediate the potential of the said cathode and the potential of the said anode.

2. The combination of claim 1 in which the anode is axially corrugated forming a plurality of inner surface portions each portion being substantially perpendicular to the plates of one of said filters opposite the said output opening of the respective filter.

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