June 20, 1939. A. L. SAMUEL 2,163,157

ELECTRON DISCHARGE APPARATUS

Filed July 22, 1937

FIG. 1

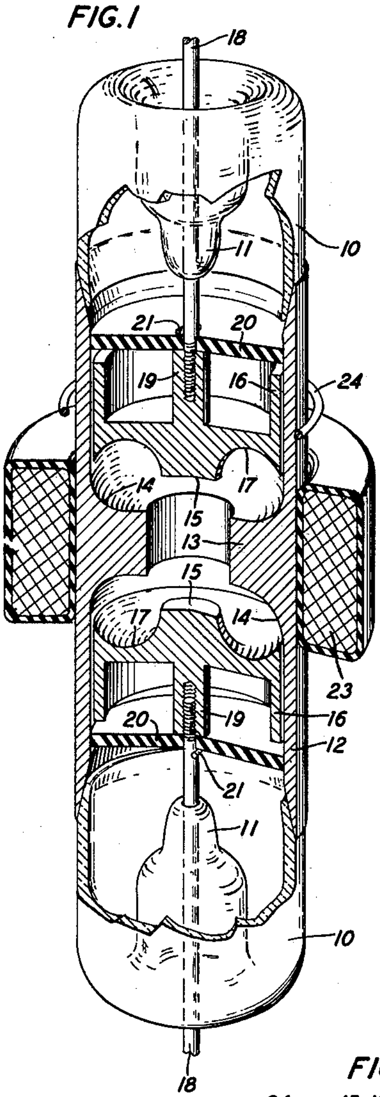


FIG. 3

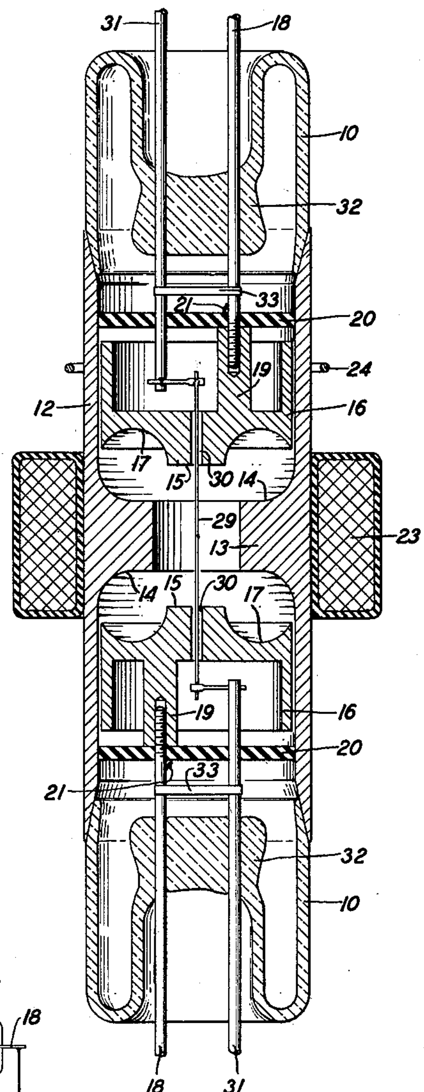


FIG. 4

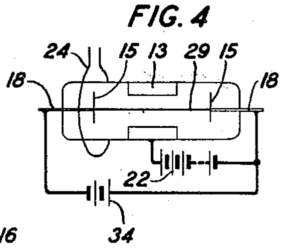
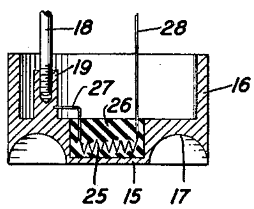


FIG. 2



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ELECTRON DISCHARGE APPARATUS

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15 Claims. (Cl. 250—27.5)

This invention relates to electron discharge apparatus and more particularly to such apparatus especially suitable for the generation and amplification of ultra-high frequency impulses.

One object of this invention is to increase the operating efficiency of electron discharge apparatus.

Another object of this invention is to facilitate the generation and amplification of impulses of extremely short wave-lengths, for example, wave-lengths of the order of one meter or less.

A further object of this invention is to simplify the structure of electron discharge apparatus and thereby to reduce the number of component elements thereof.

In one illustrative embodiment of this invention, electron discharge apparatus comprises a pair of spaced cathodes having opposed electron emitting surfaces, and an anode between the cathodes and outside of the peripheries of the electron emitting surfaces thereof. These surfaces may be coated with a material having good secondary emitting properties. During operation of the apparatus, electrons emanating from one of the cathodes flow to and impinge upon the other cathode and cause the emission of secondary electrons therefrom. These secondary electrons in turn flow toward the first cathode, impinge thereon and cause the emission of other secondary electrons therefrom. Inasmuch as each electron impinging upon a cathode causes the release of a plurality of secondary electrons, a repeated electron multiplication occurs at the cathodes. Eventually some of the electrons between the cathodes are attracted to the anode and constitute an oscillating current.

In accordance with one feature of this invention, the cathodes and the anode have juxtaposed surfaces defining inductances of predetermined magnitudes which together with the interelectrode capacitances provide a tuned circuit resonant to the frequency at which the apparatus is intended to operate. The cathodes and the anode may have other juxtaposed portions forming direct current blocking condensers in the anode-cathode circuit.

In accordance with another feature of this invention, a thermionic cathode is provided between the two opposed cathodes aforementioned and may be electrically connected thereto at its ends, and means are provided for producing a magnetic field adjacent and parallel to the thermionic cathode. The thermionic cathode and the anode constitute elements of a magnetron, oscillation of which is initiated by the emission of electrons from the thermionic cathode. The oscillatory current is augmented by the secondary electrons emitted from the opposed cathodes, these cathodes oscillating substantially in phase because of the electrical connection therebetween provided by the thermionic cathode.

The invention and the foregoing and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is an elevational view in perspective of electron discharge apparatus constructed in accordance with this invention, portions thereof being broken away to show the various elements more clearly;

Fig. 2 is a detail cross-sectional view of a modification of the cathodes shown in Fig. 1;

Fig. 3 is an elevational view in cross-section of electron discharge apparatus illustrative of another embodiment of this invention; and

Fig. 4 is a diagrammatic view illustrating the external electrical association of the electrodes of the device shown in Fig. 3.

Referring now to the drawing, the electron discharge device shown in Fig. 1 comprises an enclosing vessel having vitreous end portions 10 provided with inwardly extending stems 11, and an intermediate metallic portion serving as the anode of the device. The metallic portion includes a cylinder 12 hermetically sealed at its ends to the vitreous portions 10, and an inwardly extending annular flange 13, preferably midway between the ends of the cylinder 12, and having annular arcuate surfaces 14.

Disposed on opposite sides of the annular flange 13 are a pair of cathodes, each of which includes a plane surface 15, preferably coated with a material having good secondary electron emitting properties, a cylindrical flange 16 adjacent and coaxial with the cylindrical portion 12 of the anode, and annular, substantially semi-cylindrical surfaces 17 coaxial with the arcuate surfaces 14. The electron emitting portions 15 preferably are of smaller diameter than the central aperture in the flange 13 and mounted parallel to and coaxial with each other. Preferably these portions 15 are spaced such a distance that the transit time of an electron flowing therebetween is commensurate with the period of the operating frequency of the device.

The cathodes may be supported by rigid rods or leading-in conductors 18 embedded in the stem 11 and threaded into central hubs 19 in the cathodes. Fitted on each of the supports 18 is an insulating disc 20 abutting the corresponding hub

19 and locked thereagainst by a stub 21 affixed to the corresponding support 18. The discs 20 are fitted within the cylinder 12 and maintain the cathodes in coaxial relation with the anode.

The juxtaposed surfaces 14 and 17, it will be apparent, bound substantially toroidal cavities and provide inductances of definite magnitudes. Preferably these surfaces are designed so that the inductances provided thereby constitute with the capacitances between the anode and the cathodes and between the cathodes a circuit within the enclosing vessel of the device, resonant to the frequency at which the device is to be operated. The cylindrical portions 12 and 16 of the anode and the cathodes respectively define direct current blocking condensers in the tuned circuits.

During operation of the device, the cathodes may be connected together directly so that they are at substantially the same mean potential. A positive potential is impressed upon the anode as by a source, such as a battery 22, shown in Fig. 4, connected directly between the anode and the cathodes, the potential being such that the fundamental period of oscillation is the same as the resonant period of the tuned circuit described heretofore. The anode may be encompassed by a cylindrical electromagnetic coil 23, which produces a substantially constant, concentrated magnetic field between the surfaces 15 of the cathodes and coaxial therewith.

When the potential is impressed upon the anode, under one mode of oscillation, the cathode surfaces 15 will be at different instantaneous potentials because of the tuned circuit therebetween. That is to say, when one surface 15 is at its maximum instantaneous potential, the other surface 15 will be at its minimum instantaneous potential. Electrons emitted from one of the cathode surfaces 15, for example the upper surface in Fig. 1, under the influence of the positive potential upon the anode will be drawn to and impinge upon the other surface 15, the lower surface in Fig. 1, the electron transit time being commensurate with the natural period of the tuned circuit coupling the cathodes. The impinging electrons will cause the emission of secondary electrons from the lower surface 15 and these secondary electrons will be attracted to the upper surface 15 and impinge thereon, causing the emission of other secondary electrons. This phenomenon of impinging electrons and the resultant emission of secondary electrons will be repeated alternately at the surfaces 15 so that there will be produced an oscillating electron field between the two cathodes. Because of the coatings on the surfaces 15, each impinging electron will cause the emission of a plurality of secondary electrons so that in effect an electron multiplication occurs at each of the cathodes during each cycle of the operating frequency.

The magnetic field produced by the coil 23 concentrates the various electron streams flowing between the cathodes, along the longitudinal axis of the device so that for several cycles at least the great majority of the electrons pass through the central aperture in the flange 13 of the anode. As the electron field between the cathodes increases, however, some of the electrons are drawn therefrom periodically and flow to the anode flange 13 and constitute the oscillating current in the anode circuit.

An output or utilization circuit may be coupled magnetically to the internal oscillating circuit of the electron discharge device as by an open-ended, looped or substantially cylindrical conductor 24 encircling the anode of the device.

As illustrated in Fig. 2, one or both of the cathodes in the device shown in Fig. 1 may be of the indirectly heated thermionic type comprising a heater filament 25 adjacent the emitting portion 15 and encased in an insulating or ceramic material 26 in a recess in the cathode. One of the leading-in conductors 27 for the filament 25 may be connected to the hub 19, which is offset as shown, and the other leading-in conductor 28 may be sealed in and extend from the stem 11.

In the embodiment of the invention illustrated in Figs. 3 and 4, a linear cathode 29, for example, a filament of thoriated tungsten, extends between the cathodes 15 and is coaxial therewith and with the anode flange 13. The cathode 29 may extend through central apertures 30 in the cathodes 15 and be supported from rigid metallic rods 31, sealed in the stems 32, by resilient members 33. Preferably the rods 31 are connected electrically to the adjacent support or leading-in conductor by metallic strips or wires 33. As shown in Fig. 4, heating current for the filamentary cathode may be supplied from a source, such as a battery 34, connected between the leading-in conductors 18, and the anode may be maintained at a positive potential with respect to all of the cathodes as by a battery 22.

During operation of the device, the magnetic field produced by the coil 23, and the potential upon the anode are so adjusted that the cathode 29 and anode constitute a magnetron element, the oscillating frequency of which will be dependent upon the interelectrode capacitances and the inductances formed by the surfaces 17, the inductances and capacitances preferably being made of such magnitude that the circuit of which they form a part is tuned to the frequency at which the device is intended to operate. The oscillating current will be augmented by the secondary electrons emanating from the surfaces 15, generated as described heretofore in connection with Fig. 1. Inasmuch as the cathodes 15 are connected directly by the filamentary cathode 29, the electron current emanating therefrom will oscillate substantially in phase and contribute simultaneously to the oscillating current of the magnetron element.

Although specific embodiments of the invention have been shown and described, it will be understood, of course, that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An electron discharge device comprising an evacuated enclosing vessel, an annular anode and a cathode having an electron emitting portion in cooperative relation with said anode, said anode and said cathode having juxtaposed annular surfaces bounding a substantially toroidal cavity and having portions separate from said surfaces defining a condenser.

2. An electron discharge device of the high vacuum type comprising a pair of spaced cathodes having opposed electron emitting surfaces, and an anode in cooperative relation with said surfaces, said anode and one of said cathodes having juxtaposed portions defining an inductance of predetermined magnitude.

3. An electron discharge device of the high vacuum type comprising an anode having an annular portion, a cathode on one side of said

portion, and a second cathode on the other side of said portion, said cathodes having opposed parallel electron emitting surfaces, and said anode and said cathodes having juxtaposed surfaces defining inductances which form a resonant circuit with the interelectrode capacitances.

4. An electron discharge device in accordance with claim 3 in which each of said cathodes has a portion cooperating with said anode to form a condenser therewith.

5. An electron discharge device comprising an evacuated enclosing vessel, an anode including a portion having an aperture therein, and a pair of cathodes on opposite sides of said portion, said cathodes having parallel secondary electron emitting portions in alignment with said aperture, and said anode and said cathodes having juxtaposed surfaces bounding substantially toroidal cavities.

6. An electron discharge device in accordance with claim 5 comprising means for producing a magnetic field between said cathodes.

7. An electron discharge device in accordance with claim 5 in which said anode and said cathodes have coaxial cylindrical portions defining condensers.

8. An electron discharge device comprising an anode having an opening therein, an elongated cathode extending through said opening, and a pair of cathodes at opposite ends of said elongated cathode and having opposed electron emitting surfaces.

9. An electron discharge device comprising a cylindrical anode, a linear thermionic cathode coaxial with said anode, and a pair of secondary electron emitting cathodes at opposite ends of said thermionic cathode and having opposed emitting surfaces.

10. An electron discharge device in accordance with claim 9 comprising means electrically connecting said secondary electron emitting cathodes to said thermionic cathode.

11. An electron discharge device comprising an anode having an apertured portion, a filamentary cathode in cooperative relation with said anode and extending through the aperture in said portion, and a pair of auxiliary cathodes adjacent opposite ends of said filamentary cathode, said auxiliary cathodes having parallel secondary electron emitting surfaces on opposite sides of said portion and in alignment with the aperture therein.

12. An electron discharge device in accordance with claim 11 comprising means electrically connecting said auxiliary cathodes to said filamentary cathode, and means for producing a magnetic field adjacent said filamentary cathode.

13. An electron discharge device comprising an anode having an annular portion, a filamentary cathode extending through said portion and coaxial therewith, means for producing a magnetic field adjacent said cathode and parallel thereto, and a pair of auxiliary cathodes on opposite sides of said portion and electrically connected to the ends of said filamentary cathode, said auxiliary cathodes having parallel, opposed secondary electron emitting portions coaxial with said filamentary cathode, and said anode and said auxiliary cathodes having juxtaposed arcuate surfaces bounding substantially toroidal cavities.

14. An electron discharge device in accordance with claim 13 in which said anode and said auxiliary cathodes have juxtaposed cylindrical portions defining condensers.

15. An electron discharge device comprising an anode having an annular portion, and a pair of cathodes on opposite sides of said annular portion having parallel, opposed electron emitting surfaces in alignment with each other and the aperture in said annular portion, resistance means electrically connecting said cathodes, said anode and said cathodes having portions defining inductances constituting a tuned circuit with the interelectrode capacitances, and said surfaces being spaced a distance such that the transit time of an electron flowing therebetween is commensurate with the period of the resonant frequency of said circuit.

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