Nov. 21, 1950 A. M. CLOGSTON **2,530,948**

ELECTRON INJECTION SPACE DISCHARGE DEVICE

Filed Oct. 21, 1948 4 Sheets-Sheet 1

FIG. 1

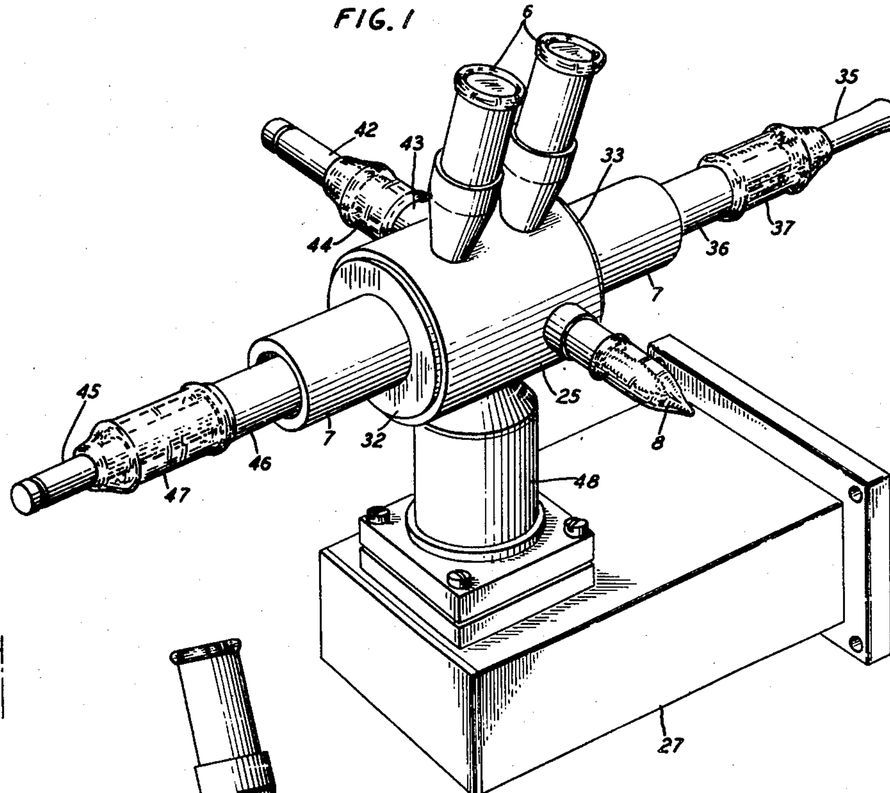
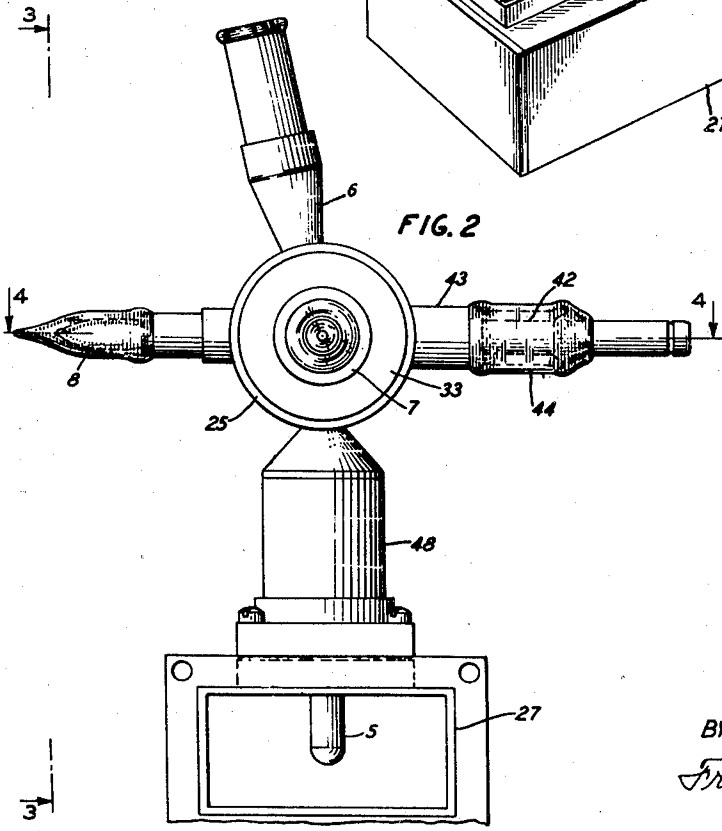


FIG. 2



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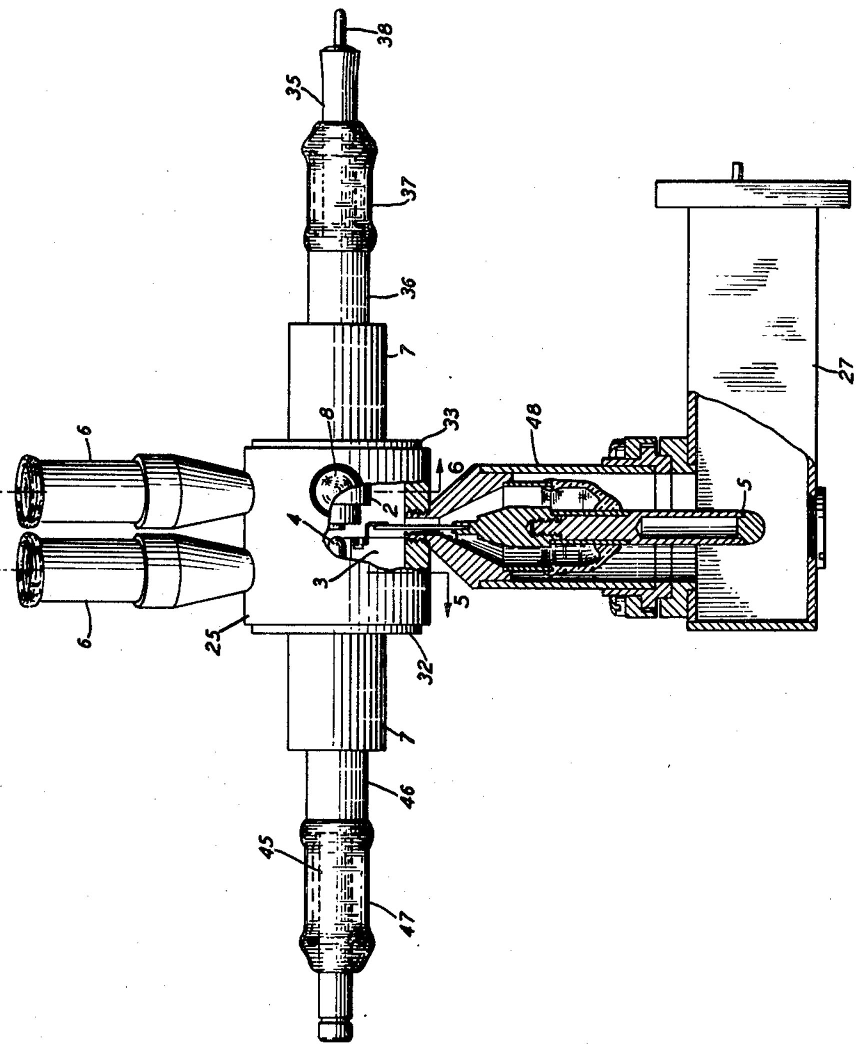
Filed Oct. 21, 1948 4 Sheets-Sheet 2

FIG. 3



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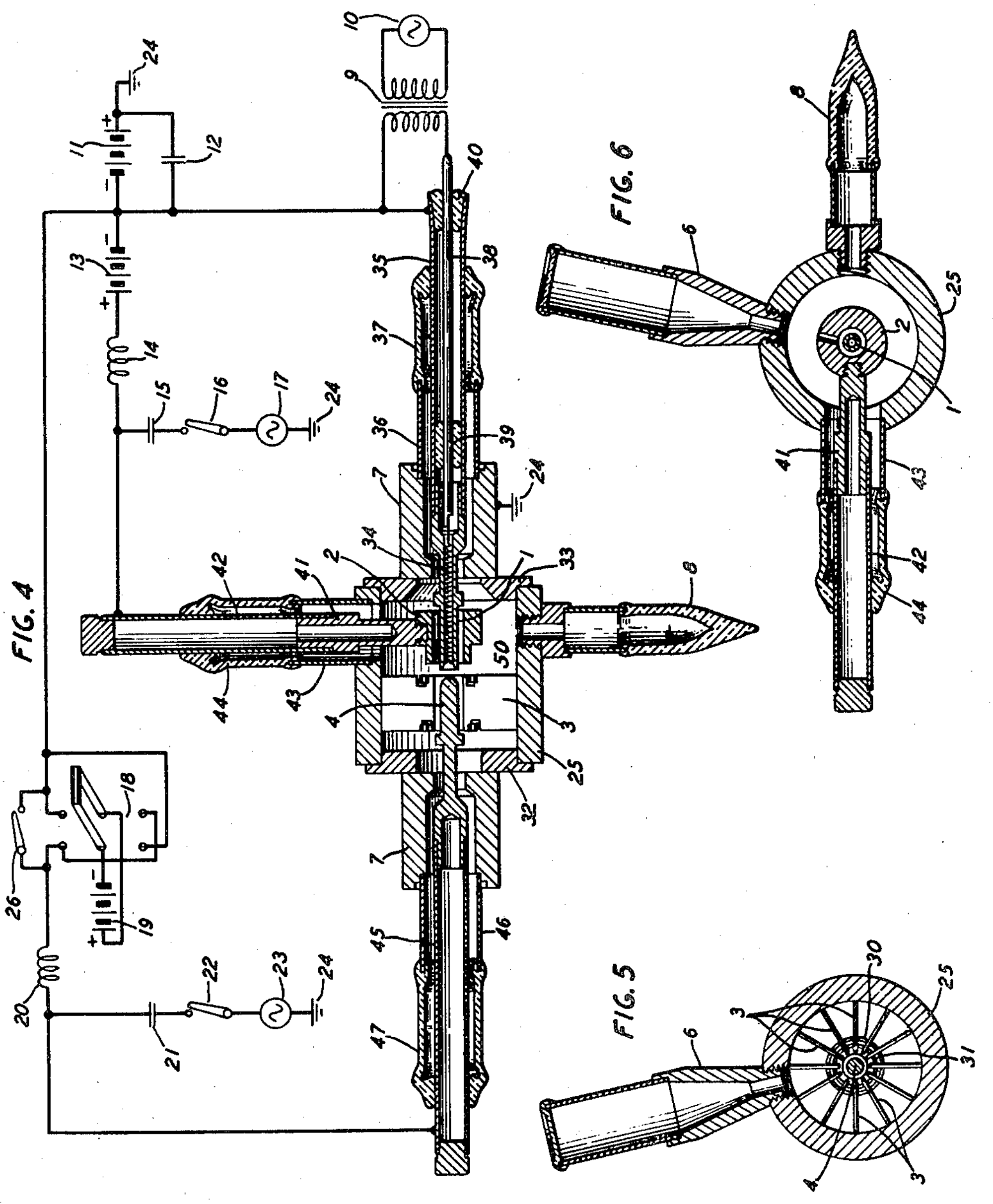

FIG. 4

FIG. 5

FIG. 6

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FIG. 7

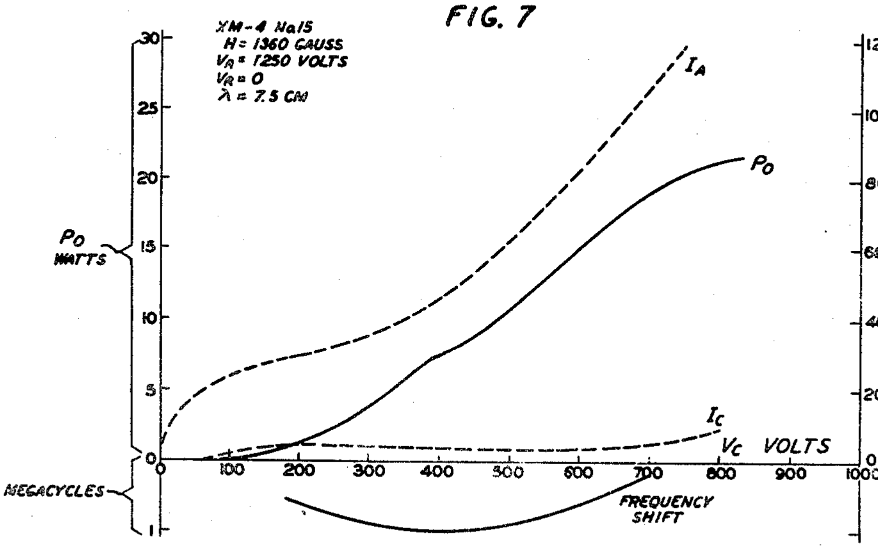
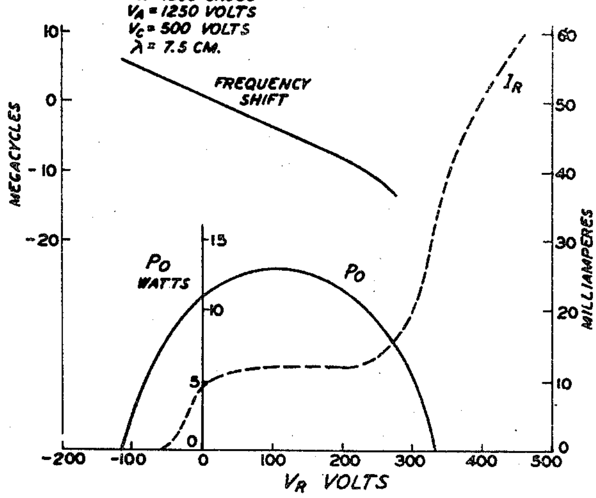


FIG. 8



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Patented Nov. 21, 1950

2,530,948

UNITED STATES PATENT OFFICE

2,530,948

ELECTRON INJECTION SPACE DISCHARGE DEVICE

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Application October 21, 1948, Serial No. 55,681

7 Claims. (Cl. 332—5)

1

This invention relates to space discharge devices such as oscillators and modulators and more particularly to electron injection devices, that is, devices in which electrons are injected into a cavity resonator from a cathode located outside the resonator.

A feature of the invention is a central rod or control electrode contained within the cavity resonator in the position ordinarily occupied by a cathode and physically and conductively separated from the cathode.

A further feature of the invention is that the resulting device is useful either as an amplitude modulator or as a frequency modulator in addition to acting as a generator of oscillations.

The invention is more particularly described hereinafter in conjunction with the drawings in which:

Fig. 1 is a perspective view showing the external appearance of the magnetron as viewed from the side;

Fig. 2 is an end view of the magnetron of Fig. 1;

Fig. 3 is a side elevational view of the device of Fig. 1 partially in section;

Fig. 4 is a longitudinal sectional view of the device of Fig. 1 sectioned as indicated by the arrow 4—4 in Fig. 2 and combined with a schematic diagram of electrical connection;

Fig. 5 is a sectional view as indicated by the arrow 5 in Fig. 3;

Fig. 6 is a sectional view as indicated by the arrow 6 in Fig. 3; and

Figs. 7 and 8 are plots of the operational characteristics of the device shown in Figs. 1 and 6 inclusive.

Referring to Figs. 1 and 6 inclusive, a cathode 1 is mounted coaxially within a hollow control electrode or control anode 2 as shown in Figs. 4 and 6. A plurality of conductive fins 3 are arranged about a center rod or central control electrode 4 as shown in Fig. 5. The center rod 4 and the cathode are mounted on a common axis, spaced longitudinally and physically separated from each other. Mode locking straps 30 and 31 are provided and may be set in notches in the fins 3 as shown in Figs. 4 and 5. Straps 30 and 31 may be placed at either or both ends of the array of fins 3 forming with the fins 3 and shell 25 an assembly comprising a hollow main anode 50, which in the device illustrated is a magnetron anode. A probe 5 is conductively connected to one of the fins 3 as shown in Fig. 3. One or more viewing tubes 6 may be provided if desired, so that internal conditions within the device may be observed visually during actual operation. The use of the viewing tube is recommended particularly in the case of experimental devices and may well be dispensed with particularly if the magnetrons are to be produced by mass production methods.

2

Magnetic pole-pieces 7 are provided at each end of the magnetron assembly for the introduction of the required magnetic field for magnetron operation in well-known manner. The pole-pieces 7 are preferably hollow, the cathode 1 being supported within and by means of one such pole-piece and the center rod 4 being supported within and by means of the pole-piece at the opposite end of the device.

A tubulation 8 is provided and sealed off after evacuation of the device in well-known manner. The cathode 1, control anode 2, fins 3 and center rod 4 are all contained within external conductive shell 25 which is shown as cylindrical and having end plates 32 and 33 to which are attached the magnetic pole-pieces 7.

The cathode 1 contains a heating element 34 and is attached to a hollow conductive tube 35 which is supported within another hollow tube 36 attached to the magnetic pole-pieces 7. The members 35 and 36 are insulatingly joined by a vitreous seal 37 which supports the member 35 and the cathode assembly. One side of the heating element 34 is connected to the cathode 1 and the other side is brought out and connected to a conductive rod 38 enclosed within the tubular element 35 and supported by insulating plugs 39 and 40 which also serve as part of the vacuum envelope of the device. The control anode 2 is conductively attached to a supporting rod 41 and a conductive tube 42 which latter is held within a hollow conductive tube 43 and spaced therefrom by means of a vitreous seal 44. The center rod 4 is conductively attached to a conductive tube 45 surrounded by another conductive tube 46, the tubes 45 and 46 being joined by a vitreous seal 47.

The probe 5 extends into a wave guide fitting 27. The probe 5 and connection thereto are surrounded by a hollow conductive tube 48 which is conductively connected to the shell 25.

A source 10 of alternating potential connected through a transformer 9 is provided for heating the heater 34 to a sufficient temperature for copious electron emission. A battery 11 is provided to produce a potential difference between the cathode 1 and the magnetron anode assembly 50, the latter comprising the fins 3, straps 30, 31 and shell 25. A potential difference of 1250 volts therebetween has been found satisfactory. A battery 13 is provided for making the potential of the control anode 2 positive with respect to the cathode 1, a potential difference between these elements of 500 volts having been found to be satisfactory. The center rod 4 may be operated at the cathode potential by closing a switch 26 which is provided as shown in Fig. 4. When desired, the center rod 4 may be operated at a potential difference with respect to the cathode 1 by opening the switch 26 and closing a reversing switch 18 thereby connecting a battery 19 in either polarity according to whether the switch 18 is thrown upward or downward.

The battery 11 may be shunted by a condenser 12. The battery 13 may have connected in series therewith a choke coil 14 which, together with a condenser 15 which may be connected by means of a switch 16, forms an alternating current input circuit for a source 17 of modulating potential which has one side connected to ground at 24. Another source of modulating potential 23 may be connected between ground 24 and through a switch 22 and a condenser 21, the center rod 4. A choke coil 20 is provided as part of the input circuit of the source 23, the coil being in series connection with the battery 19 when the switch 18 is closed.

In the operation of the arrangement of Figs. 1 to 6 inclusive, when a suitable magnetic field is supplied by way of the pole-pieces 7, the device will oscillate to produce electromagnetic waves over a wide range of operating condition. A magnetic field of 1360 gauss has been found satisfactory when established between the pole-pieces 7. The operating values given are illustrative only and are not intended to limit the invention. Under the conditions given, the device will deliver approximately 10 watts into the wave guide 27 by means of the probe antenna 5, provided the wave guide 27 is terminated in a matched impedance. Approximately 60 milliamperes will flow to the oscillatory circuit 50 and approximately 3 milliamperes will flow to the control anode 2.

The mode of operation is believed to be as follows: Electrons emerge from the hot cathode 1 under the influence of the voltage on the control anode 2 and move in orbits about the cathode because of the combined effects of the magnet field existing between the pole-pieces 7 and the electric field between the cathode 1 and anode 2. These electrons build up a dense space charge that causes some of the electrons to drift longitudinally along the axis of the tube into the interaction space between the center rod 4 and the oscillatory circuit 50. In this region the electrons are subjected to a strong radial electric field because of the negative potential on the center rod 4. Interacting with this electric field and with the magnetic field, the electrons move in orbits around the center rod in such a way as to be in angular resonance with any radio frequency field existing in the oscillator circuit. This action in this region is in every way similar to that occurring in a conventional magnetron and results in the same oscillation.

It will be noted that the device illustrated differs from a conventional magnetron in that the electrons do not originate in the immediate region of the oscillatory circuit but are injected into this region from a cathode displaced axially a short distance from the oscillatory circuit. Because of this physical separation of the cathode and oscillatory circuit, control of the electron flow is not limited to the effect of the plate voltage from the battery 11 as is usually the case but is also susceptible to control by the magnitude of the control anode voltage from the battery 13. The effect of this voltage upon the operation of the magnetron is shown in Fig. 7.

Referring to Fig. 7, it is to be observed that a change in the control anode voltage V_C varies the output power P_O and the current I_A flowing to the oscillatory circuit. It is clear that if an oscillatory voltage is superimposed on the direct current voltage supplied to the control anode 2, the magnetron can be amplitude-modulated to a high degree. Because very little current flows through the control anode 2, as indicated by the plot of I_C in Fig. 7, the modulation can be effected with the use of a very small amount of modulating power. In a conventional magnetron, a similar modulation produced by varying the plate voltage as from the battery 11, is very expensive in terms of modulating power. In Fig. 4, the source 17 of modulating power is shown in position to be connected to the control anode 2 by closing the switch 16. The choke 14 insures that a high impedance will be offered to the source 17. In order to provide against a change in the potential of the cathode 1 due to any change in the current in the internal resistance of the battery 11, this battery is by-passed by the condenser 12.

The device shown is adaptable, by means of design modifications which will be evident to those skilled in the art, to make the device suitable for higher voltage operation. A further advantage of the increased separation of the cathode from the oscillatory circuit, appears in high voltage operation due to the non-exposure of the cathode to high electric field gradients.

The actual physical separation of the cathode 1 from the center rod 4 is also advantageous. Because of this separation, it is possible to vary the electric gradient in the interaction space between the center rod 4 and the oscillatory circuit 50 without changing the potential between the cathode 1 and the oscillatory circuit 50. This operation can be carried out by opening the switch 26 and inserting a voltage from the source 19 through the reversing switch 18 into the connection to the center rod 4. The effect of varying the potential of the battery 19 is shown in Fig. 8. As the voltage V_R of the center rod with respect to the cathode 1 changes from −100 volts to +300 volts, the power output P_O goes from zero to a maximum value and back to zero again. Over this range, the frequency shifts by 20 megacycles per second. Over a limited range from zero to +200 volts, it is observed by reference to Fig. 8 that the current flowing to the center rod changes very little. This is the most useful range of the characteristic for best results in frequency modulation. Over this range the power changes by less than 1 decibel while the frequency shifts by 10 megacycles per second. No similar simple means has been available in conventional magnetrons for varying the frequency. A frequency variation can be effected for an ordinary magnetron by varying the plate voltage, but this variation is accompanied by a large change in output power. If an alternating potential of about 100 volts peak value is superimposed upon a direct-current voltage of +100 volts applied to the center rod 4, a frequency modulation with a 10-megacycle per second deviation is effected. This result can be achieved, as indicated in Fig. 8, by closing the switch 22 thereby applying the potential of the modulating source 23 to the center rod 4 through the condenser 21. Like the choke 14, the choke 20 helps to provide a high impedance load for the source 23.

It will be evident to those skilled in the art that the invention may be embodied in other forms than that illustrated herein without exceeding the scope of the invention as defined in the appended claims.

What is claimed is:

1. A space discharge device comprising a cathode and a central control electrode non-emissive of secondary electrons coaxially mounted and spaced apart from each other longitudinally, a hollow control anode surrounding said cathode, and a main anode surrounding said central control electrode.

2. A space discharge device comprising a hollow anode, a central control electrode non-emissive of secondary electrons surrounded by and mounted within said anode, a cathode external to said anode and spaced apart from said central control electrode and from said anode, means adjacent to said cathode to draw electrons away from said cathode, and means adjacent to said cathode and said anode to inject electrons so drawn away from said cathode into the space between said anode and said central control electrode.

3. A space discharge device comprising a cavity resonator, a main anode mounted within said cavity resonator and having a central hollow space therein, a central control electrode non-emissive of secondary electrons mounted within the said central hollow space of said main anode and insulated from said cavity resonator and said main anode, a cathode spaced apart from said central control electrode and mounted coaxially with the same and insulated from said cavity resonator and said main anode, and a hollow control electrode mounted coaxially with said cathode and surrounding the same and insulated from said cavity resonator and said main anode.

4. An injection magnetron comprising a cavity resonator, a cathode centrally mounted within said cavity resonator, a hollow control electrode surrounding said cathode, a central control electrode non-emissive of secondary electrons mounted within said cavity resonator coaxially with said cathode and longitudinally displaced therefrom, and means adjacent to said cathode and said central control electrode to maintain a steady magnetic field within said cavity resonator in the direction of the common axis of said electrodes.

5. An injection magnetron comprising a cavity resonator, a cathode centrally mounted within said cavity resonator, a hollow control electrode mounted coaxially with said cathode and surrounding the same, a central control electrode non-emissive of secondary electrons mounted within said cavity resonator coaxially with said cathode and longitudinally displaced therefrom, a main anode mounted within said cavity resonator coaxially with said central control electrode and surrounding the same, and means adjacent to said cathode and said central control electrode to maintain a steady axial magnetic field within said cavity resonator.

6. A self-oscillatory amplitude modulator comprising a cavity resonator, a cathode of a space discharge device mounted within said cavity resonator, a central control electrode mounted coaxially with said cathode and spaced longitudinally therefrom, a hollow control anode surrounding said cathode, a main anode surrounding said central control electrode, means maintaining said cathode and said central control electrode at a common potential, a source of supply current connected to said main anode, and a source of modulating potentials connected between said cathode and said hollow control anode.

7. A self-oscillatory frequency modulator comprising a cavity resonator, a cathode of a space discharge device mounted within said cavity resonator, a central control electrode mounted coaxially with said cathode and spaced longitudinally therefrom, a hollow control anode surrounding said cathode, a main anode surrounding said central control electrode, means maintaining said hollow control anode at a positive potential with respect to said cathode, a source of supply current connected to said main anode, and a source of modulating potentials connected between said central control electrode and said cathode.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,409,038	Hansell	Oct. 8, 1946
2,438,194	Steele et al.	Mar. 23, 1948