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D. R. HAMILTON

2,581,408

HIGH-FREQUENCY ELECTRON DISCHARGE DEVICE

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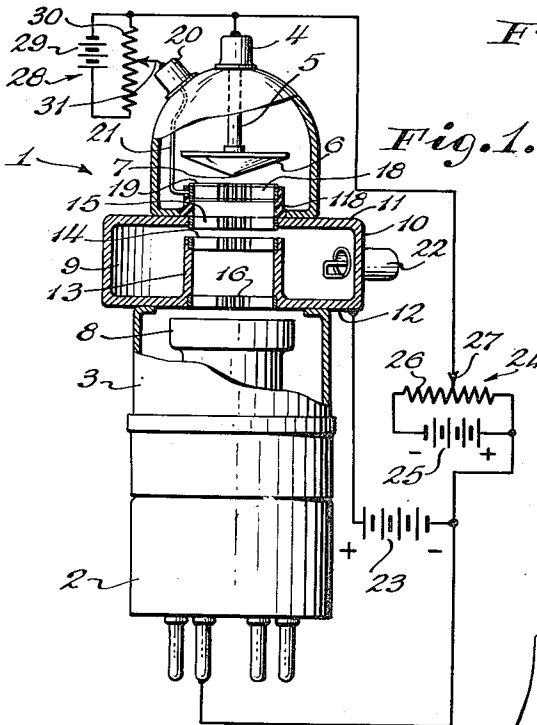


Fig. 2.

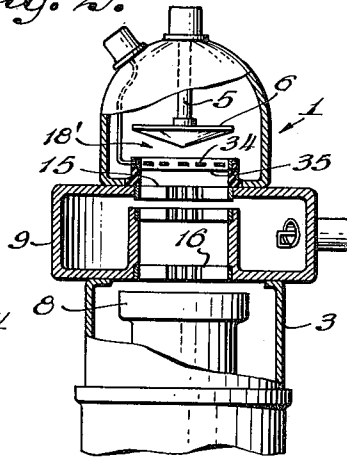


Fig. 1A.

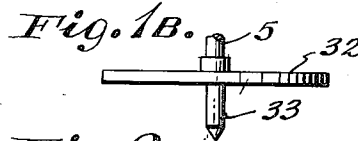
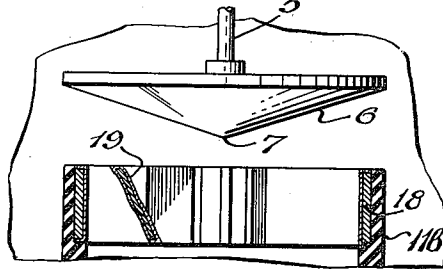


Fig. 2A.

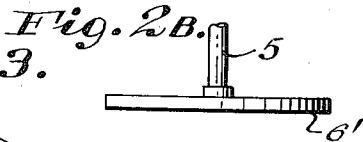
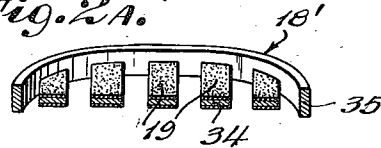
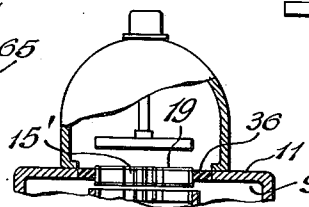
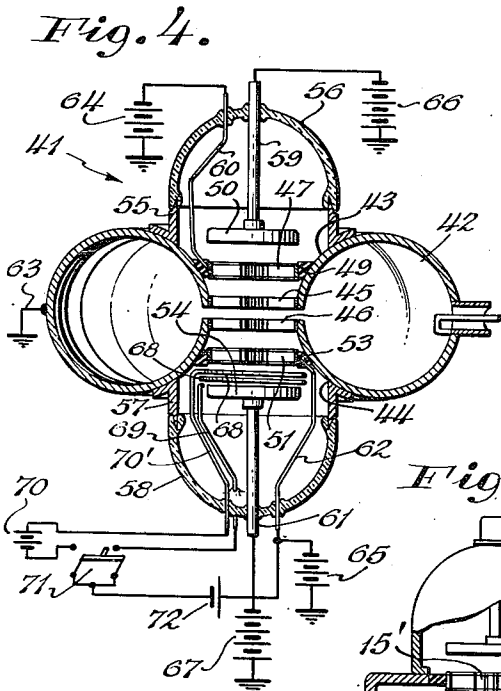


Fig. 3.



INVENTOR
DONALD R. HAMILTON
BY
Paul B. Hunter,
ATTORNEY

UNITED STATES PATENT OFFICE

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HIGH-FREQUENCY ELECTRON DISCHARGE
DEVICEDonald R. Hamilton, Princeton, N. J., assignor to
The Sperry Corporation, a corporation of Dela-
ware

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16 Claims. (Cl. 315—5)

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The present invention relates to the art including ultra-high-frequency electron discharge devices utilizing cavity resonators as frequency-determining elements thereof. In one aspect, it is more particularly directed to such electron discharge devices utilizing secondary emissive electrodes for increasing the power output of such tubes.

The present invention is particularly applicable to the single cavity resonator electron discharge device known as a reflex Klystron and shown in Fig. 2 of U. S. Patent No. 2,250,511 for Oscillator Stabilization System, granted July 29, 1941.

A reflex Klystron comprises a cathode, a cavity resonator having a pair of electron-permeable walls aligned with the cathode, and a reflector or repeller electrode beyond the cavity resonator. In operation, the electron beam from the cathode is velocity modulated by the oscillating electromagnetic field within the resonator to become density modulated in the bunching space between the cavity resonator and reflector, and is redirected through the resonator to give up energy to the field and sustain its oscillations.

It is an object of the present invention to provide an improved cavity resonator ultra-high-frequency electron discharge device utilizing a secondary-emissive electrode.

It is another object of the present invention to provide an improved reflex Klystron capable of producing large power output.

It is still another object of the present invention to provide a novel single resonator electron discharge device in which secondary cathodes are disposed on both sides of the resonator.

It is yet another object of the present invention to provide a novel cavity resonator electron-discharge device in which the necessity of a continuously operating primary cathode is obviated.

The invention also relates to the novel features or principles of the instrumentalities described herein, whether or not such are used for the stated objects, or in the stated fields or combinations.

In accordance with one aspect of the invention, a secondary-emissive grid structure is provided intermediate the resonator and the reflector of a reflex Klystron, whereby the redirected density-modulated beam impinges upon the secondary-emissive grid structure and produces a density-modulated secondary beam of greater power. The enhanced beam produces a greater power output from the reflex Klystron. In a preferred embodiment, the secondary-emissive grid structure is biased and positioned with respect to the

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resonator to minimize the transit time of the density-modulated secondary beam between the grid and the resonator whereby the debunching of the density-modulated secondary beam is minimized.

In accordance with another aspect of the invention, there is provided an electron discharge device having a single cavity resonator in which there are electron-permeable openings in opposing walls; a secondary-emissive grid structure disposed on each side of the cavity resonator and aligned with the electron-permeable openings; and a reflector beyond each secondary-emissive grid and also aligned with said openings. With proper choice of operating potentials on the various elements of the device, a self-sustaining oscillator results, thereby eliminating the necessity of providing a primary source of electrons during operation.

In the drawings,

Fig. 1 is an elevation view, partly in section, of an improved reflex Klystron in which a secondary-emissive grid is positioned between the resonator and the reflector, together with a schematic circuit diagram for such Klystron;

Fig. 1A is an enlarged fragmentary view in section, showing the secondary-emissive grid and the reflector of the apparatus of Fig. 1;

Fig. 1B is a view in section of a spiked reflector that may be substituted for the conical or V-shaped-cross-section reflector of Figs. 1 and 1A;

Fig. 2 is an elevation view, partly in section of another embodiment of the invention in which a ribbon grid is utilized in place of the deep thin-walled grid of Fig. 1;

Fig. 2A is a fragmentary view in section of the ribbon grid of Fig. 2;

Fig. 2B is a fragmentary view in section of a flat reflector that may be utilized in place of the V-shaped reflector of Figs. 1 and 2;

Fig. 3 is a fragmentary view in section of a modification of the resonator and secondary-emissive grid of the apparatus of Figs. 1 and 2;

Fig. 4 is an elevation view in section of another aspect of the invention in which a secondary-emissive grid and a reflector are disposed on each side of the resonator.

Referring to Fig. 1 and Fig. 1A, there is shown an evacuated ultra-high-frequency discharge device 1 having a conventional pronged base 2 sealed to the lower portion of vacuum envelope 3, disposed within the lower portion of which is a cathode 8. Affixed to the top end of the vacuum envelope 3 is a metallic terminal cap 4 from which a lead 5 extends to a conical or V-shaped-

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cross-section reflector or reflector electrode 6 within vacuum envelope 3, the apex 7 of the V-shaped reflector 6 extending away from lead 5 and facing cathode 8. Thus, the configuration of reflector electrode 6 is such as to provide it with a centrally projecting portion.

Intermediate cathode 8 and reflector 6 is a re-entrant resonator 9 having an outer cylindrical wall 10 forming a portion of the vacuum envelope 3, and having an upper conductive end wall 11 and a lower conductive end wall 12. Positioned within and coaxial with resonator outer wall 10 is the resonator inner cylinder 13 which is rigidly fixed to lower end wall 12 and extends toward upper end wall 11. An entrance grid 14, aligned with cathode 8, is positioned at the end of inner cylinder 13 adjacent upper end wall 11 and an exit grid 15 is positioned within upper end wall 11 and aligned with cathode 8 and entrance grid 14. Positioned within inner cylinder 13 and adjacent lower end wall 12 is accelerating grid 16. Cylinder 113 formed of insulating material surrounds exit grid 15 and is fixed to and extends upwardly from upper end wall 11. Positioned at the upper end of cylinder 113 and fixed thereto is grid 18 which is coated with efficient secondary emissive material 19.

Affixed to upper end of vacuum envelope 3 is terminal cap 20 which is connected to secondary emissive grid 18 by lead 21. Extending through outer resonator wall 10 is coaxial line terminal 22, which is utilized for extracting energy from resonator 9.

Connected between cathode 8 and resonator 9 is potential source 23, whose positive and negative terminals are connected to resonator 9 and cathode 8, respectively, whereby an electron-accelerating potential is provided between accelerating grid 16 and cathode 8. In order to operate reflector 6 at a potential negative with respect to the cathode 8, variable voltage source 24 is connected therebetween. It comprises battery 25 and resistor 26 in shunt, resistor 26 having a variable tap 27. Cathode 8 is connected to the positive terminal of battery 25 and reflector 6 is connected to the variable tap 27, through lead 5 and terminal cap 4.

In order to operate secondary-emissive grid 18 at a potential positive with respect to reflector 6, variable voltage source 28 is provided. It comprises battery 29 and resistor 30 in shunt, resistor 30 having a variable tap 31. The negative terminal of battery 29 is connected to reflector 6 and variable tap 31 of resistor 30 is connected to secondary-emissive grid 18 through terminal cap 20 and lead 21.

In operation, electrons from cathode 8 are accelerated in the space between cathode 8 and accelerating grid 16 and are projected as a substantially constant-intensity beam through the gap between entrance grid 14 and exit grid 15 of resonator 9, where they are velocity-modulated by the oscillating field in resonator 9. The velocity-modulated beam is bunched in the space between exit grid 15 and reflector 6, and, because of the negative potential on reflector 6, substantially all of the electrons are redirected towards the resonator 9.

As shown in Fig. 1A, the walls of the secondary-emissive grid 18 are comparatively thin, but have appreciable depth. Therefore, grid 18 intercepts comparatively few electrons flowing from exit grid 15 toward reflector 6. However, because of the V-shape of reflector 6, the reflected electrons travel along spreading paths different from

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their initial paths, and a substantial portion of the reflected electrons is intercepted by secondary-emissive grid 18 during their return toward resonator 9. Although a V-shaped reflector is used in this apparatus to cause the return paths of the electrons to be different from their initial paths, it is not intended that the invention be restricted to only that means for producing the desired results. Other means known to the art may be used, for example, another form of non-planar reflector, such as the spiked reflector shown in Fig. 1B, which comprises a flat plate 32 and a spike 33 at the center of flat plate 32 and extending downward toward the secondary-emissive grid 18 and which may be substituted for reflector 6 of Fig. 1.

The returned electron beam is essentially a density-modulated or bunched beam, and the secondary electron beam, created by the impingement of the bunched primary beam on the secondary-emissive grid 18, is therefore also a density-modulated beam. Because of the potential difference between secondary-emissive grid 18 and exit grid 15 of resonator 9, the density-modulated secondary beam is projected through exit grid 15 to give up energy to the oscillating field within resonator 9. The unintercepted portion of the density-modulated primary beam is also projected through exit grid 15 and also gives up energy to the oscillating field. Substantially all the electrons of the primary and secondary beams are collected on the inner walls of the resonator 9 and of the inner cylinder 13 after interaction with the oscillating field within resonator 9. Inasmuch as the secondary to primary ratio of secondary-emissive material may be of the order of 25 or higher, it can be seen that the power output of the reflex Klystron is appreciably increased by the insertion of a secondary-emissive grid intermediate its resonator and reflector.

The operation of such a device is further improved by operating the secondary emissive grid at an appreciable potential difference from the resonator, even though physically close to the resonator. By this operation of the device of Fig. 1, the transit time of the secondary electrons between the secondary-emissive grid 18 and the exit grid 15 is minimized and, therefore, debunching of the secondary beam is substantially prevented, resulting in an improvement in the efficiency of operation of the novel apparatus.

Referring to Figs. 2 and 2A, there is shown a modification of the apparatus of Fig. 1 which utilizes a flat ribbon secondary-emissive grid 18' instead of the thin deep-wall grid shown in Fig. 1. Grid 18' is made up of a series of parallel flat ribbons 34 positioned within and rigidly fastened to outer ring 35, the grid 18' being coated with efficient secondary emissive material 19. The operation of the apparatus of Fig. 2 is similar to the operation of the apparatus of Fig. 1. However, the major electron intercepting surface of grid 18' is now perpendicular to the axis of the electron beam, whereas the grid 18 of Fig. 1 has its major intercepting surface substantially parallel to the axis of the electron beam.

The operation of the apparatus of Fig. 2 is further improved by proper choice of potential difference between the grid 18' and resonator 9. It is known that the number of secondary electrons emitted from a secondary-emitting surface due to impingement of a primary beam varies with variation in primary impact energy over a limited range of primary impact energies, even

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though the density of the primary beam be constant. The electron beam emerging from resonator 9 and arriving at the secondary-emissive grid 18' is a velocity-modulated beam of substantially constant density. Inasmuch as the average velocity of the electrons in the velocity-modulated beam at the secondary-emissive grid 18' is a function of the accelerating voltage between the accelerating grid 16 and cathode 8 less the retarding voltage between exit grid 15 and secondary emissive grid 18', the average velocity of the velocity-modulated beam at grid 18' may be adjusted to be within the above-mentioned limited range by adjusting the potential on grid 18'. At this operating potential, that portion of the velocity-modulated electron beam which is intercepted by the bottom faces of the flat ribbons 34 produces a density-modulated secondary beam that is projected through the oscillating field in resonator 9 by the accelerating voltage between secondary emissive grid 18' and exit grid 15 of resonator 9 to give up energy to the field. That portion of the velocity-modulated beam that is not intercepted by the secondary-emissive grid 18' during initial traversal toward the reflector becomes density-modulated in the space between the secondary-emissive grid 18' and reflector 6 and produces a second density-modulated secondary beam when it impinges upon the secondary-emissive grid 18' during return to the resonator 9. This action is similar to the action of the apparatus of Fig. 1 and, as in Fig. 1, the second density-modulated secondary beam is projected through the oscillating field within resonator 9 to give up energy to the field. Thus, it can be seen that, with proper choice of potential difference between secondary-emissive grid 18' and exit grid 15, energy is given up to the oscillating field by a density-modulated secondary beam produced under the influence of a velocity-modulated primary beam of substantially constant density in addition to the energy given up by a density-modulated secondary beam produced under the influence of a density-modulated primary beam.

A flat reflector 6', as shown in Fig. 2B, may be utilized in place of the V-shaped reflector 6 of the apparatus of Fig. 2.

Fig. 3 shows a modification of a portion of the apparatus of Figs. 1 and 2, in which the resonator exit grid 15' is coated with efficient secondary-emissive material as at 19 and is insulated from upper end wall 11 of resonator 9 by insulating ring 35. As so constructed, the single exit grid 15' may be utilized in place of the combination of exit grid and secondary-emissive grid of the apparatus of Figs. 1 and 2.

Fig. 4 shows another aspect of the invention in which a reflector and a secondary-emissive grid are disposed on each side of the resonator in order to eliminate the necessity of a primary cathode during operation. The novel ultra-high-frequency electron discharge device 41 includes toroidal cavity resonator 42, having upper and lower opposing reentrant wall portions 43 and 44 in which are positioned grids 45 and 46, respectively. Aligned with grid 45 and above resonator 42 is grid 47 which is coated with secondary-emissive material and which is fixed to, but insulated from, resonator 42 by insulating ring 49. Beyond secondary-emissive grid 47 is reflector or reflector electrode 50. Below resonator 42 and aligned with grid 46 is grid 51, which is also coated with secondary emissive material and

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is fixed to, but insulated from, resonator 42 by insulating ring 53. Positioned below secondary-emissive grid 51 is reflector or reflector electrode 54.

The upper portion of the vacuum envelope includes a metallic cylinder 55 joined to upper wall 43, coaxial with resonator 42, and sealed to a glass dome 56. The lower portion of the vacuum envelope includes a metallic cylinder 57 joined to lower wall 44, coaxial with resonator 42, and sealed to glass dome 58. Brought out through upper glass dome 56 are leads 59 and 60 which are connected to upper reflector 50 and upper secondary-emissive grid 47 respectively, and brought out through lower glass dome 58 are leads 61 and 62 which are connected to lower reflector 54 and lower secondary-emissive grid 51 respectively.

Resonator 42 is grounded at 63 and, for maintaining secondary-emissive grids 47 and 51 at potentials negative with respect to resonator 42, there are provided voltage sources 64 and 65 whose positive terminals are grounded and whose negative terminals are connected respectively to secondary-emissive grids 47 and 51 through respective leads 60 and 62. Secondary-emissive grids 47 and 51 are preferably operated at the same potential. For maintaining reflectors 50 and 54 negative with respect to secondary-emissive grids 47 and 51 and to resonator 42, there are provided voltage sources 66 and 67 whose positive terminals are grounded and whose negative terminals are connected respectively to reflectors 50 and 54 through respective leads 59 and 61. Reflectors 50 and 54 are preferably also operated at the same potential.

Electron current flow through resonator 42 is initiated by a helical starting filament or cathode 68 which is positioned between the lower reflector 54 and lower secondary-emissive grid 51. The helical starting filament 68 is coaxial with grids 46 and 51 and its diameter is substantially the same as their diameters. Connected to one end of helical filament 68 is lead 70' which is brought out through lower glass dome 58 and which is connected to positive terminal of battery 70. Connected to the other end of helical filament 68 is lead 69 which is also brought out through lower glass dome 58 and which is connected to one terminal of a three terminal switch 71. Connected to the second terminal of switch 71 is the negative terminal of battery 70 and connected to the third terminal is the negative terminal of battery 72 whose positive terminal is connected to lower secondary-emissive grid 51 through lead 62. In the closed position of switch 71, the three terminals are joined together electrically and, in the open position, each terminal is disconnected from the other two. In the closed position, battery 70 is connected across filament 68, causing electron emission therefrom, and battery 72 is connected between filament 68 and lower secondary-emissive grid 51, putting filament 68 at a potential intermediate the potentials of lower secondary-emissive grid 51 and lower reflector 54. In the open position of switch 71, filament 68 is disconnected from both batteries 70 and 72 and hence no longer emits electrons and is cut out of the circuit.

In the closed position of switch 71, the substantially constant intensity electron beam from starting filament 68 is velocity-modulated by the field in resonator 42. Part of the electron beam impinges upon the upper secondary-emissive

grid 47 and produces a secondary beam whose velocity is substantially unmodulated and which is redirected through resonator 42 by the accelerating voltage between upper secondary-emissive grid 47 and resonator 42.

Electrons passing through the upper secondary-emissive grid 47 are bunched to form a density-modulated beam which is redirected by upper reflector 50 toward secondary-emissive grid 47 and resonator 42. As more fully explained in connection with the apparatus of Figs. 1 and 2, part of the reflected density-modulated primary electron beam impinges upon secondary-emissive grid 46 and produces a density-modulated secondary beam that is projected through the oscillating field within resonator 42, to give up energy to the field in addition to the energy given up to the field by the unintercepted portion of the reflected density-modulated primary beam.

The secondary beam whose velocity is unmodulated and which is obtained from upper secondary-emissive grid 47 traverses resonator 42 from upper resonator grid 45 to lower grid 46 and is velocity-modulated by the field in resonator 42. In a manner similar to that described in connection with the initial beam from filament 68, a secondary beam whose velocity is unmodulated is created by impingement of part of the velocity-modulated beam upon lower secondary-emissive grid 51 and is redirected through resonator 42 by the accelerating voltage between lower secondary-emissive grid 51 and resonator 42. Oscillations within resonator 42 are sustained by the action of the velocity-modulated beam in passing through the lower secondary-emissive grid 51, and in becoming a density-modulated beam, as more fully explained in connection with the apparatus of Figs. 1 and 2. The secondary beam whose velocity is unmodulated and which is obtained from grid 51 traverses resonator 42 from lower grid 46 to upper grid 45 and the process is repeated to maintain oscillations within resonator 42. After oscillations have been initiated, starting filament 68 is electrically removed from the circuit by opening switch 71.

Thus, the present invention provides a reflex Klystron capable of producing large power output. In accordance with one aspect of the invention, the large power output is produced by the positioning of a secondary emissive grid intermediate the reflector and the resonator of the reflex Klystron.

The present invention further provides a novel cavity resonator electron discharge device in which the necessity of a continuously operating primary cathode is obviated.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention would be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An ultra-high-frequency electron-discharge device comprising a resonator having a pair of aligned electron permeable walls, a cathode disposed on one side of said resonator and aligned with said walls, a reflector disposed on the other side of said resonator and a secondary-emissive grid structure intermediate said resonator and said reflector.

2. An ultra-high-frequency electron discharge device comprising a resonator having a pair of

aligned electron permeable walls, two secondary-emissive grids each disposed on an opposite side of said walls and aligned therewith, two reflector electrodes each disposed on an opposite side of said grids and aligned therewith, and a cathode disposed between one of said electrodes and an adjacent one of said grids.

3. An ultra-high-frequency electron-discharge device comprising means for producing an electron beam; means in said device for density-modulating said electron beam including means along the path of said beam for velocity-modulating the electron beam and means electrically coupled to said beam including a reflector and defining a bunching space wherein the velocity-modulated beam is converted into a density modulated beam; and a secondary-emissive electrode in the path of said electron beam.

4. A device as in claim 3 wherein said secondary-emissive electrode is a grid, said grid having a flat ribbon construction.

5. A device as defined in claim 2, wherein said secondary-emissive electrode is a grid, said grid having a thin deep-wall construction.

6. An ultra-high-frequency electron-discharge device comprising means for producing an electron beam; means along the path of said beam for velocity-modulating the electron beam, a secondary-emissive electrode in the path of said velocity-modulated beam; and means beyond said secondary-emissive electrode including a reflector and defining a bunching space wherein said velocity-modulated beam is converted into a density modulated beam.

7. A device as defined in claim 6 wherein said reflector has a centrally-projecting portion, said portion extending substantially in the direction of said velocity-modulating means.

8. A device as defined in claim 6 wherein said velocity-modulating means includes a cavity resonator having a pair of grid means, one of said grid means providing said secondary-emissive electrode.

9. A device as defined in claim 6, further including a further secondary-emissive grid along the path of said beam and interposed between said electron beam producing means and said velocity-modulating means.

10. A device as defined in claim 9, further including a further reflector aligned with said beam path and positioned adjacent said beam producing means.

11. A device as defined in claim 6 wherein said beam producing means includes a helical filament.

12. A device as defined in claim 6, further including a further reflector and a further secondary emissive electrode, said further reflector and further electrode beam disposed adjacent said electron beam producing means.

13. A device as defined in claim 12, wherein said beam producing means includes a helical filament.

14. An ultra-high-frequency electron discharge device comprising means for producing an electron beam, a cavity resonator having a pair of grids, said grids being aligned along the path of said beam, said resonator effecting velocity modulation of said beam, and a reflector electrode spaced from said grids and aligned along said beam path, whereby said velocity-modulated beam is converted into a density-modulated beam, said grid closest to said electrode being electrically insulated from said resonator and being a secondary-emissive grid.

15. An ultra-high-frequency electron-discharge

device comprising means for producing an electron beam; means in said device for density-modulating said electron beam including means coupled to said beam for velocity-modulating the electron beam and means coupled to said beam including a reflector electrode and defining a bunching space for converting the velocity modulated beam into a density modulated beam; and a secondary-emissive grid located at a distance along the path of said density modulated portion of the beam.

16. Ultra-high-frequency apparatus comprising means for producing a beam of electrons, means along the path of said electron beam for velocity-modulating said beam of electrons, a non-planar reflector electrode beyond said velocity-modulating means, and a secondary-emissive grid struc-

ture intermediate said reflector electrode and said velocity-modulating means.

DONALD R. HAMILTON.

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