

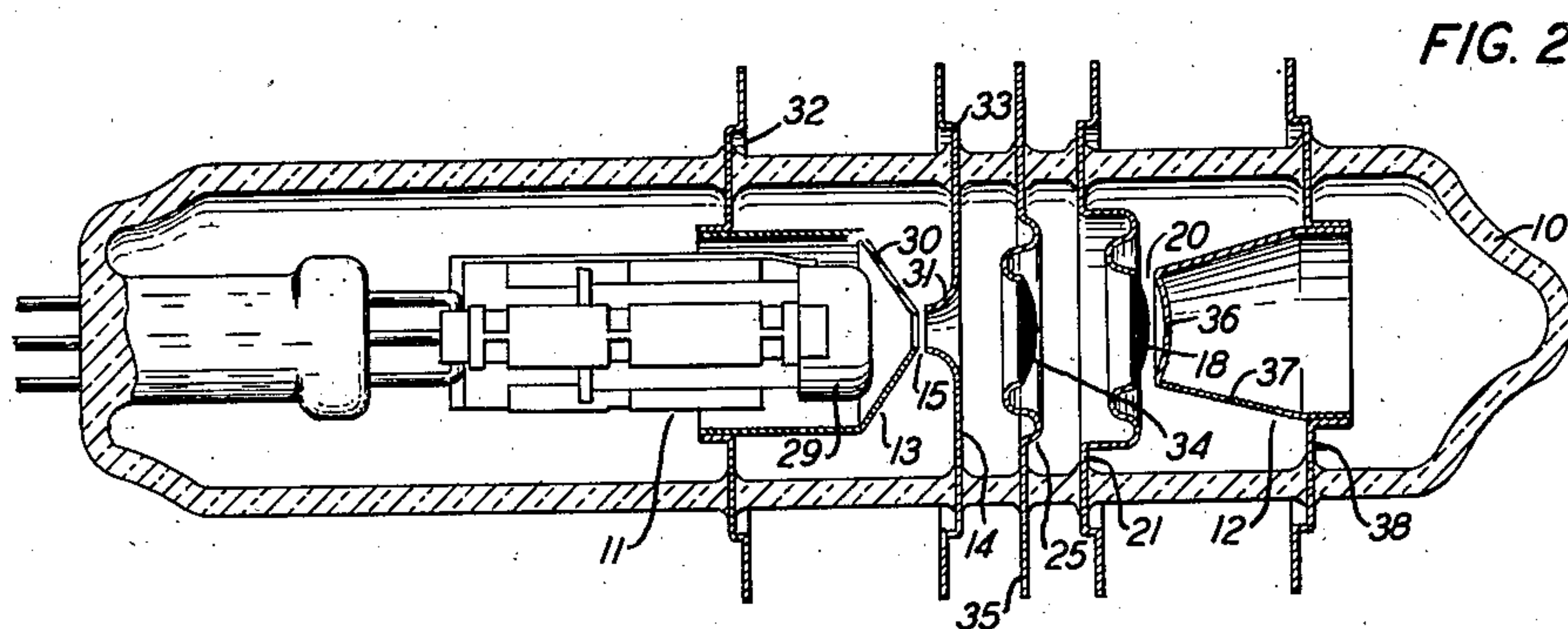
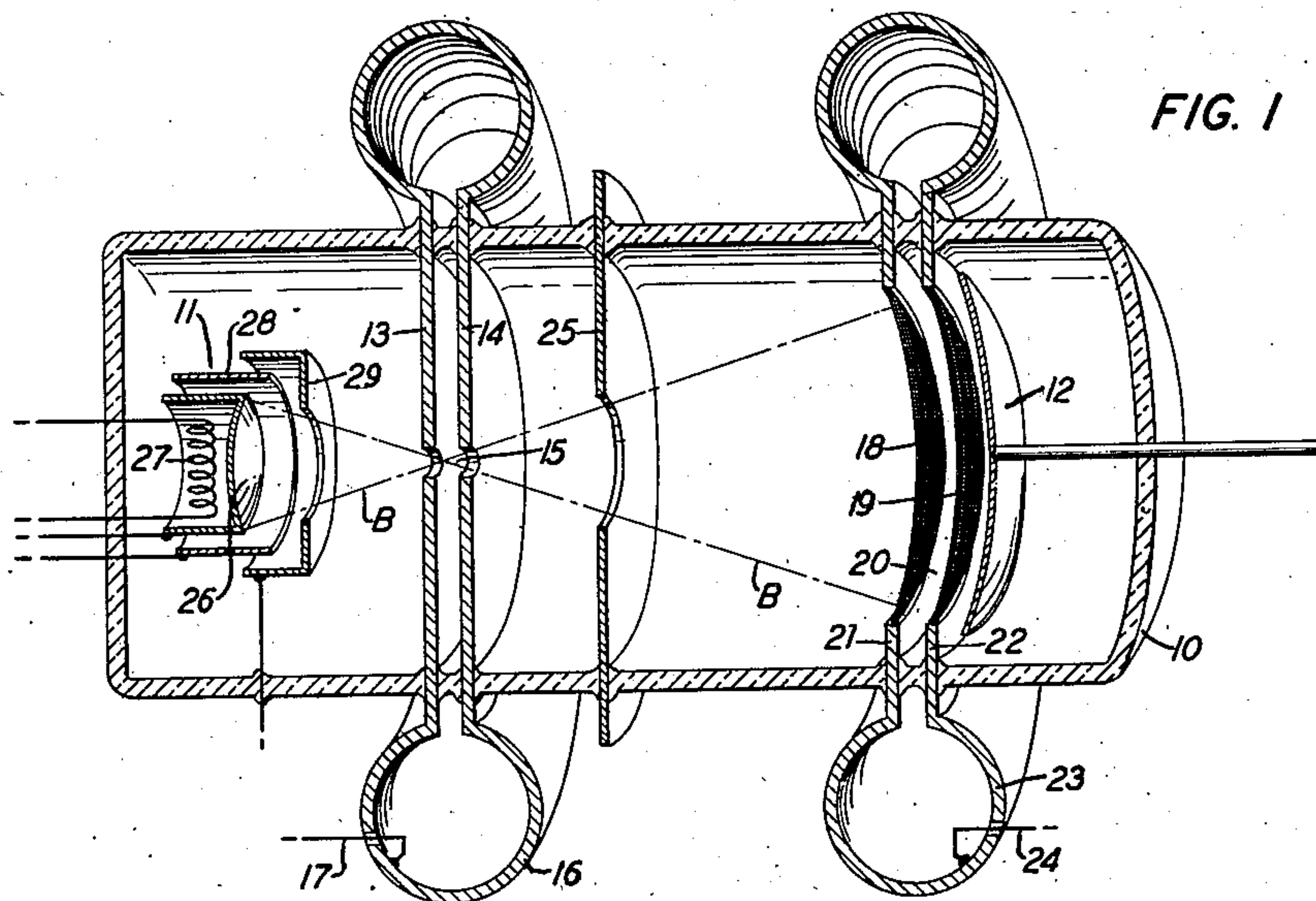
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J. O. McNALLY

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ELECTRON DISCHARGE DEVICE

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INVENTOR  
J. O. McNALLY

BY

Walter C. Kiesel

ATTORNEY



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## ELECTRON DISCHARGE DEVICE

James O. McNally, Maplewood, N. J., assignor to  
Bell Telephone Laboratories, Incorporated,  
New York, N. Y., a corporation of New York

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This invention relates to electron discharge devices and more particularly to such devices of the velocity variation type and especially suitable for use as amplifiers at frequencies corresponding to wave-lengths in the centimeter range.

Velocity variation devices of one known type operable as amplifiers comprise in general two spaced pairs of electrodes having associated therewith suitable conductors, such as substantially closed metallic bodies, defining with the electrodes resonant circuits such as cavity resonators. An electron stream is projected across the gap between one pair of electrodes and is subjected to a radio frequency field, resulting from the excitation of the circuit of which these electrodes form a part, whereby the stream is velocity varied. The velocity varied stream traverses a drift space wherein the electrons are bunched or grouped and the velocity variations are converted into density variations. The density varied stream then crosses the gap between the other pair of electrodes and delivers energy to the circuit constituted in part by this pair of electrodes.

A general object of this invention is to improve the structure and operating characteristics of electron discharge devices of the velocity variation type. More specifically, objects of this invention are:

To simplify the structure of velocity variation type electron discharge devices;

To reduce noise effects in such devices particularly adapted for operation as amplifiers;

To reduce space charge degrouing effects in the drift space of velocity variation devices and thereby to obtain a relatively sharp grouping of the electrons projected across the output gap;

To obtain a substantially cophasic projection of the electrons in the groups or bunches produced in the drift space into the output gap;

To realize substantially equal transit times for the electrons in the groups or bunches, in traversing the output gap;

To enable operation of velocity variation devices at relatively low electrode potentials; and

To obtain a high transconductance for velocity variation type electronic amplifiers.

In one illustrative embodiment of this invention, an electron discharge device of the general construction described hereinabove comprises an electron gun constructed and arranged to produce a concentrated, converging electron stream focussed upon substantially the mid-point of the input gap and the electrodes bounding the out-

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put gap are constructed to provide an output gap of relatively large dimensions, normal to the direction of projection of electrons thereinto, as compared with the corresponding dimensions of the input gap. The electron stream after being velocity varied at the input gap traverses the drift space and in this space is permitted to diverge substantially freely so that when it reaches the output gap its cross section is comparable to that of the output gap.

In accordance with another feature of this invention, the portion of the electrode nearest the drift space and bounding the output gap is so shaped and related to the input gap and drift space that substantially equal length paths are provided for all electrons in the beam between the input gap and this portion of the electrode mentioned. In one specific form and in a device employing an axially symmetrical beam, the portion of the electrode bounding the inlet end of the output gap is a grid conforming to a segment of a spherical surface having its center of curvature substantially at the input gap. In such construction, each electron is projected into the output gap substantially normal to the elemental area of the grid which it passes.

In accordance with a further feature of this invention, the portion of the other electrode bounding the output gap is shaped to conform to the portion of the electrode bounding the inlet end of the output gap, whereby substantially equal transit times for all the electrons in the bunches or groups are obtained across the output gap.

The invention and the above-noted 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 a diagrammatic view of an electron discharge device and associated cavity resonators illustrative of one embodiment of this invention; and

Fig. 2 is an elevational view mainly in section of an electron discharge device constructed in accordance with this invention.

The apparatus illustrated diagrammatically in Fig. 1 comprises an evacuated enclosing vessel 10, for example of insulating material, adjacent the ends of which there are mounted an electron gun, designated generally as 11, and a collector or target electrode 12. Adjacent the electron gun 11 are a pair of centrally apertured electrodes 13 and 14, spaced to define a gap 15 and having associated therewith an annular shell 16 to define



an input cavity resonator. Energy may be supplied to the cavity resonator through a coupling loop 17.

Mounted adjacent the collector or target electrode 12 are a pair of electrodes having inner grid portions 18 and 19 defining a gap 20 and having also outer annular portions 21 and 22 respectively engaged by an annular shell 23 which, together with the electrodes, defines an output cavity resonator. Energy may be taken from the output cavity resonator through a coupling loop 24.

A centrally apertured electrode 25, the function of which will be set forth hereinafter is mounted between the input and output gaps 15 and 20.

The electron gun 11 comprises a cathode having a dished electron emissive surface 26, a heater filament 27 within the cathode, a beam forming electrode 28 encompassing the cathode and an accelerating anode 29 mounted between the cathode and the input gap 15. The electrodes constituting the electron gun 11 are constructed and arranged, for example as disclosed in Patent 2,268,197, granted August 8, 1941, to John R. Pierce, so as to concentrate the electrons emanating from the surface 26 into a converging conical beam indicated by the broken lines B in Fig. 1. The electron gun and the electrodes 13 and 14 are so constructed and arranged that the beam B is focussed upon substantially the mid-point of the gap 15.

During operation of the device, the beam forming electrode 28 may be maintained at substantially cathode potential and the accelerating anode 29, the input gap defining electrodes 13 and 14 and the output gap defining electrodes 18 and 19 may be maintained at positive direct current potentials relative to the cathode. The collector electrode 12 may be operated at the same direct current potential as the output gap defining electrodes and the electrode 25 may be biased at a potential lower than that of the positive electrodes relative to the cathode. As a specific illustration, in a device of the construction illustrated in Fig. 2 and described in detail hereinafter, the accelerating anode may be operated at the order of 100 volts positive, the input and output gap defining electrodes operated at the order of 100 volts positive and the electrode 25 operated at the order of 50 volts positive, all with respect to the cathode.

As noted hereinabove, the electrons emanating from the cathode surface 26 are concentrated into a converging beam focussed upon substantially the mid-point of the input gap 15. In crossing this input gap, the electrons in the beam are subjected to a radio frequency field as the result of a signal impressed upon the input cavity resonator by way of the coupling loop 17. Consequently, the electrons are velocity varied, that is some electrons are accelerated and others decelerated depending upon the phase relation of their time of injection into the gap to the radio frequency field. The beam issuing from the input gap 15, then, is composed generally of accelerated and decelerated electrons or, relatively speaking, of fast moving and slower moving electrons. In the space between the aperture in the electrode 15 and the grid 18, which is commonly referred to as the drift space and is substantially radio frequency field free, the faster moving electrons overtake the slower moving electrons so that, the drift space being made of appropriate length, the velocity variations are converted into density

variations and electrons cross the output gap 20 in time spaced bunches, delivering their energy to the output cavity resonator. Because of the lower potential of the electrode 25 relative to the potential of the input gap defining electrodes 13 and 14, the electron transit time through the drift space is increased so that a high degree of electron bunching and a correspondingly large percentage of conversion of velocity variations into density variations are realized.

As indicated by the broken lines in Fig. 1, in the drift space the electrons diverge because of their mutually repulsive charges and are permitted to do so freely up to the grid 18 bounding the inlet end of the output gap 20. The grids 18 and 19 are curved as shown, for example so as to conform to segments of spherical surfaces having their center of curvature at substantially the input gap and of an arc slightly greater than the arc of the divergent beam at the grid 18. After traversing the gap 20 and delivering energy to the output cavity resonator the electrons flow to the collector or target electrode 12.

It will be noted that because of the focussing of the beam upon the input gap 15, impingement of electrons upon the electrode 13 is minimized and, consequently, noise effects attributable to interception of electrons by the elements defining the input gap are likewise minimized. Also the apertures in the electrodes 13 and 14 may be made of very small diameter so that a very close coupling between the radio frequency field of the cavity resonator and the electron beam and also a substantial uniformity of the transit angle across the input gap, of the electrons in the beam together with a substantial uniformity of effect of the field upon the electrons constituting the beam are achieved.

It will be appreciated further that inasmuch as throughout the drift space the electron beam is permitted to diverge freely, space charge effects are minimized. Consequently, debunching of the electrons due to space charge is substantially prevented and, conversely, a relatively sharp bunching or grouping of the electrons is effected whereby a highly efficient conversion of the velocity variations into density variations is realized.

It will be noted further that because of the configuration of the grids 18 and 19 and their relation to the divergent beam, substantially all electrons traverse paths of substantially the same length between the input and output gaps, are projected into the output gap, substantially normal to the incremental area across which each electron passes and substantially equal transit angles for all electrons projected across the output gap 20 are obtained whereby the electrons in each group or bunch deliver energy to the output cavity resonator substantially in phase.

It will be appreciated also that the invention enables operation of velocity variation devices at relatively small voltages upon the electrodes and, further, provides a relatively simple structure.

Although the invention has been described as embodied in a device having axially symmetrical aligned electrodes and wherein a point focus beam is employed, it may be practiced also in devices of the type wherein a line focus beam, that is a beam of rectangular cross section normal to the direction of projection thereof, is utilized. In such devices, the apertures in the electrodes 13, 14 and 25 and the grids 18 and 19 would be rectangular and aligned and the electron gun would be constructed, as disclosed for example in



Patent 2,268,196 granted August 8, 1941, to John R. Pierce, to produce a concentrated beam of rectangular cross section focussed on a line at substantially the mid-point of the input gap. The grids 18 and 19 would conform to segments of a cylinder and have their centers of curvature substantially at the input gap. A particular advantage of such a line focus beam device is that at the retarding electrode 25 the beam is of relatively large cross section and as a result, a relatively high transconductance is obtainable.

In the electron discharge device illustrated in Fig. 2, the input gap defining electrodes 13 and 14 have central juxtaposed frusto-conoidal portions 30 and 31 respectively, the smaller ends of which are aligned and in juxtaposition, being spaced from one another, for example of the order of .015 inch. These electrodes include also outer annular portions 32 and 33, respectively, sealed hermetically to the insulating or vitreous enclosing vessel 10 and extending therethrough for connection to a shell such as the shell 16 shown in Fig. 1. The electron gun 11 is positioned within the electrode 13 and the accelerating anode 29 thereof has its outer end within the frusto-conoidal portion 30.

The retarding electrode 25 comprises a central grid 34 which is carried by a metallic annulus 35 hermetically sealed to and projecting through the wall of the enclosing vessel.

The first of the output gap defining electrodes includes a central grid portion 18 and an outer annular portion 21 sealed to and extending from the enclosing vessel 10. The output gap 20 is bounded by the grid 18 and the portion 36 of the collector electrode 12, which portion conforms to the grid 18 to provide a gap of equal length throughout. The collector electrode 12 includes also a frusto-conical portion 37 secured to a metallic annulus 38 sealed to and projecting through the wall of the enclosing vessel. A resonator shell, similar to the shell 23 in Fig. 1, may be connected to the annular members 21 and 38 and defines with the electrodes a cavity resonator to which energy is delivered by the electrons flowing across the output gap.

Although specific embodiments of the invention have been shown and described, it will be understood that they are but illustrative and 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 of the velocity variation type comprising a first pair of electrodes having closely spaced apertured portions defining an input gap, a second pair of electrodes having spaced apertured portions defining an output gap in alignment with said input gap, said first and second pairs of electrodes extending transversely with respect to the axis of alignment of said input and output gaps and said output gap being of substantially greater dimensions normal to the axis of alignment of said gaps than said input gap, means bounding a drift space between said input and output gaps, and means opposite the end of said input gap farthest from said drift space for projecting an electron stream into said input gap.

2. An electron discharge device comprising means defining an input cavity resonator, said means comprising a pair of metallic members having unobstructed apertured portions spaced in close relation and defining a gap, a cathode opposite and in alignment with said apertured

portions, means for concentrating the electrons emanating from said cathode into a converging electron beam substantially focussed upon said gap, and means defining an output cavity resonator, including a second pair of closely spaced metallic members defining a gap in axial alignment with said first gap, the one of said second pair of members nearest said first gap having an aperture therein adjacent said second gap which is of greater dimensions normal to the axis of alignment of said gaps than the apertures in said apertured portions, the space between said gaps being substantially field free whereby electrons issuing from said first resonator diverge in flowing to said second gap.

3. An electron discharge device of the velocity variation type comprising a pair of electrodes having closely spaced portions defining an input gap, means to one side of said gap for projecting an electron stream thereacross, and a second pair of electrodes to the other side of said input gap having spaced portions defining an output gap in alignment with said input gap, said output gap being of substantially greater dimensions normal to the line of alignment of said gaps than said input gap, said first and second spaced portions extending transversely to said line, and the gap bounding portion of the electrode of said second pair nearest said input gap conforming to a substantially circularly dish surface, the concave face of which is toward said input gap.

4. An electron discharge device in accordance with claim 3 wherein the gap bounding portion of the other of said second pair of electrodes conforms to said gap bounding portion of the electrode of said second pair nearest said input gap.

5. An electron discharge device of the velocity variation type comprising a pair of electrodes having closely spaced portions defining an input gap and provided with axially aligned circular apertures, an electron gun mounted to one side of said gap, said gun including a cathode and means for concentrating electrons emanating from said cathode into a beam of circular cross section to be projected across said gap, and a second pair of electrodes mounted one behind the other and to the opposite side of said input gap and having closely spaced portions defining an output gap, the gap defining portion of the electrode of said second pair nearest said input gap being circular and reticulated, of greater diameter than said apertures, in axial alignment with said circular apertures and conforming to a segment of a sphere, and the concave face of said reticulated portion being toward said input gap.

6. An electron discharge device in accordance with claim 5 wherein the gap defining portion of the other electrode of said second pair conforms to said reticulated portions.

7. An electron discharge device of the velocity variation type comprising a pair of electrodes having closely spaced portions defining an input gap and provided with axially aligned circular apertures, an electron gun mounted to one side of said input gap, said gun including a cathode and means for concentrating the electrons emanating from said cathode into a converging conical beam substantially focussed upon said input gap, an electrode mounted to the opposite side of said input gap and having a circular reticulated portion in axial alignment with said cir-



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cular apertures, said reticulated portion being of a substantially greater diameter than said apertures and conforming to a segment of a sphere, the concave surface of said reticulated portion facing said input gap and having its center of curvature substantially at said input gap, and another electrode having a portion in

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juxtaposition to said reticulated portion and defining an output gap therewith.

8. An electron discharge device in accordance with claim 7 wherein said portion of said last-mentioned electrode conforms to said reticulated portion.

JAMES O. McNALLY.