

Oct. 22, 1946.

A. L. SAMUEL

2,409,644

ELECTRON DISCHARGE APPARATUS

Filed April 11, 1941

FIG. 1

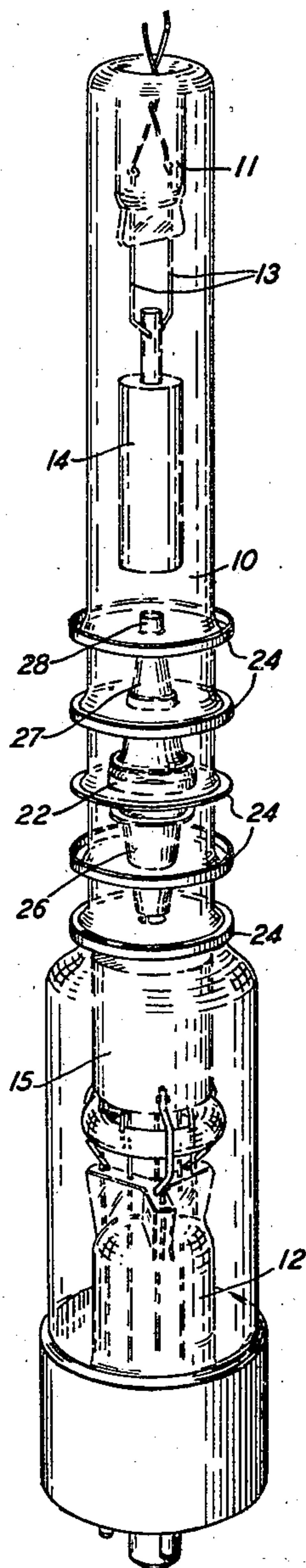


FIG. 2

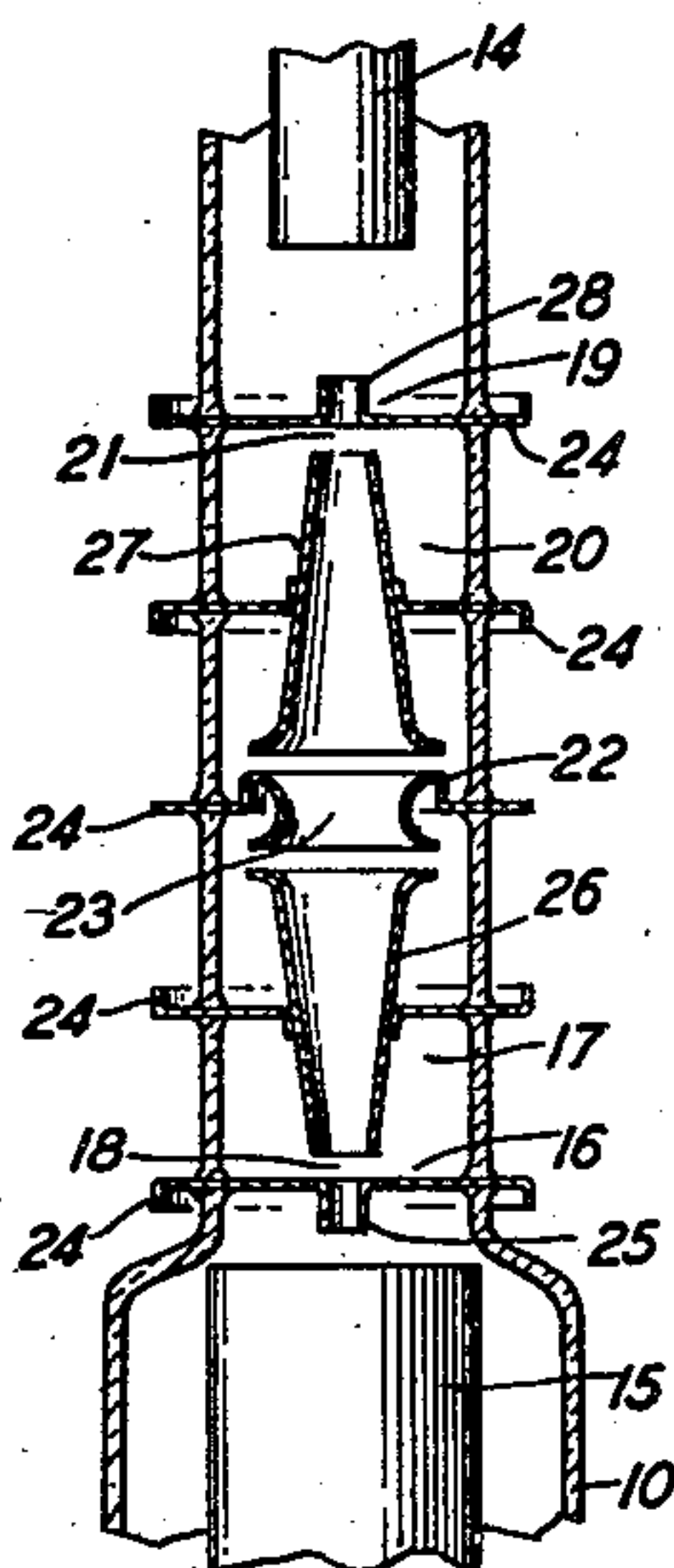


FIG. 4

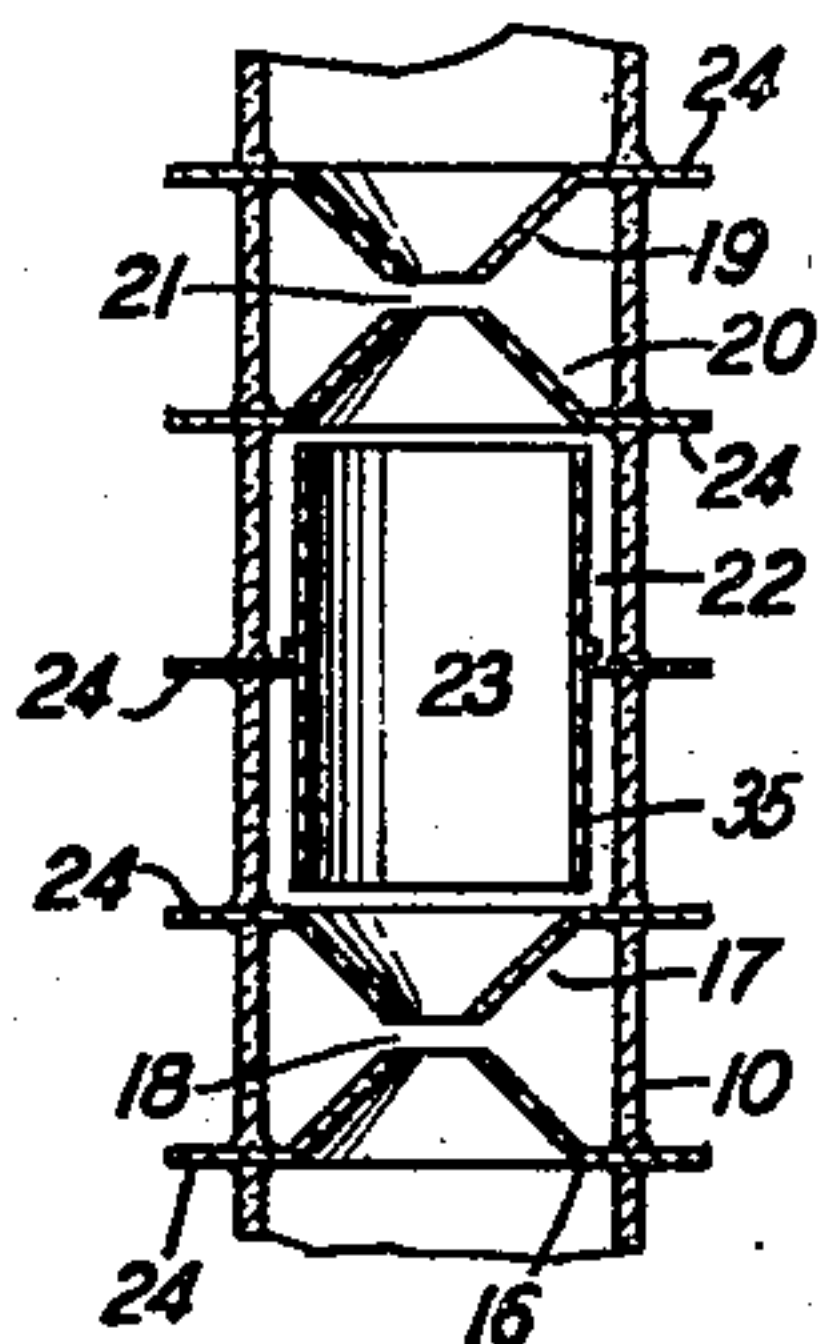


FIG. 5

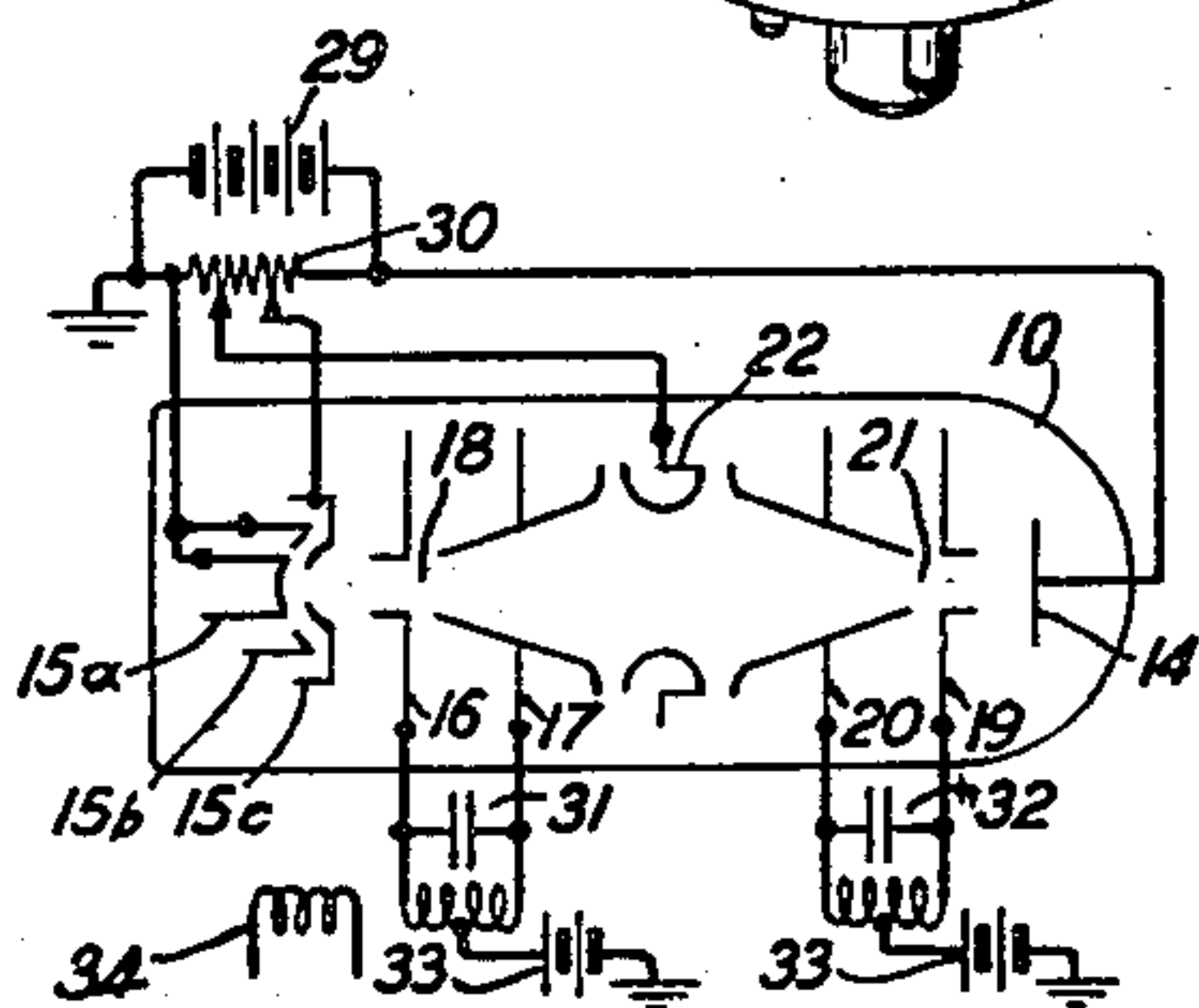
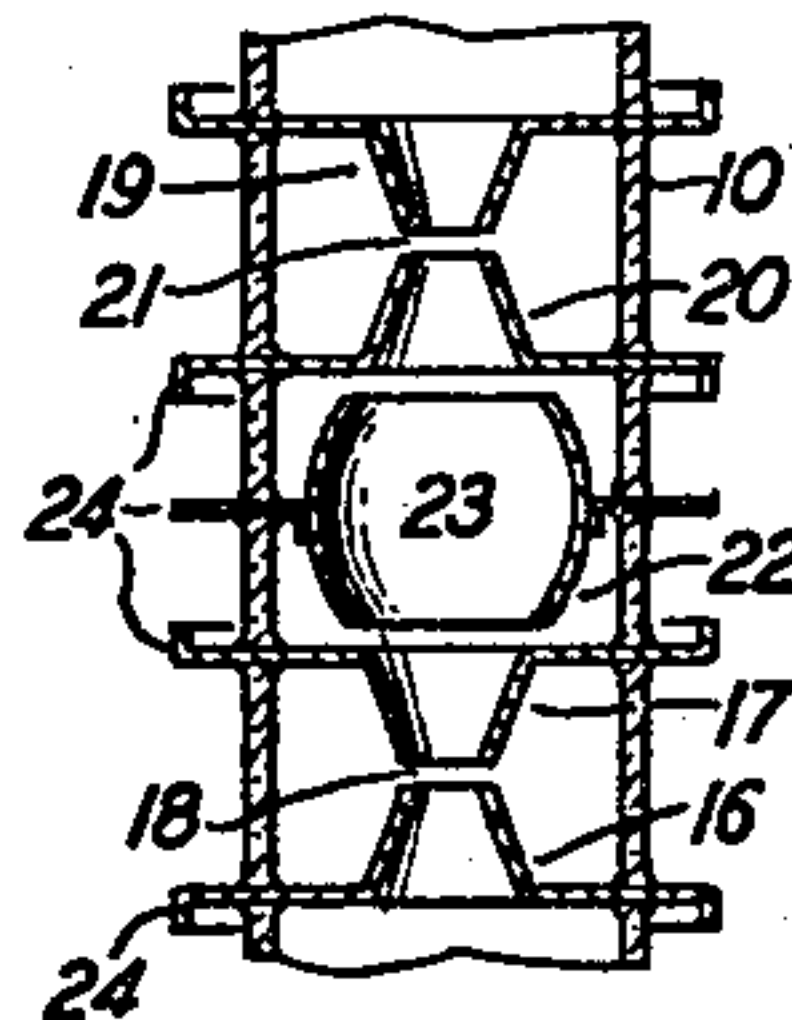


FIG. 3

INVENTOR
A. L. SAMUEL

BY

Walter C. Kiesel

ATTORNEY

UNITED STATES PATENT OFFICE

2,409,644

ELECTRON DISCHARGE APPARATUS

Arthur L. Samuel, Summit, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 11, 1941, Serial No. 388,031

5 Claims. (Cl. 250—27.5)

1

This invention relates to electron discharge apparatus and more particularly to such apparatus including electron beam discharge devices of the velocity variation type.

Velocity variation discharge devices comprise, in general, an electron gun for producing an electron beam which is accelerated toward and projected through a region wherein the beam is subjected to a cyclically varying field and thereby velocity varied. The velocity varied beam is then converted into a density varied beam and the latter flows toward an output element to which it delivers energy. In one form of such devices, the velocity variations are converted into density variations by projecting the velocity varied beam into a space, commonly designated as a drift space, wherein a periodic bunching of the slow moving and fast moving electrons in the beam is effected. The operating characteristics, such as the transconductance and percentage of density variation, of such a device are dependent to a large extent upon the effect produced in the drift space.

One general object of this invention is to improve the operating characteristics of electron beam discharge devices of the velocity variation type and, more particularly, to increase the efficacy of the drift space in such devices.

More specifically, objects of this invention are to:

Increase the transconductance of electron beam discharge devices of the velocity variation type;

Decrease the length of the drift space in velocity variation discharge devices;

Enable control of the gain of such devices;

Provide an electrostatic means for focusing the electron beam;

Increase the bunching of the electrons in the drift space whereby a high percentage density variation is produced; and

Decrease space charge effects in the drift space of such devices.

In one illustrative embodiment of this invention, an electron discharge device comprises an electron gun, means including a pair of electrodes defining an input space or gap through which the electron beam emanating from the gun is projected and wherein the beam is velocity varied, means including a second pair of electrodes defining an output space or gap, and an electrode intermediate the input and output spaces or gaps bounding a section of a drift space into which the velocity varied beam is projected and wherein the

2

velocity variations are converted into density variations.

In accordance with one feature of this invention, the electrode bounding the section of the drift space is maintained at substantially cathode potential whereby the beam upon entering the drift space is subjected to a retarding field.

In accordance with another feature of this invention, the electrodes defining the input space or gap are so constructed and arranged that the beam in passing therethrough suffers a divergence so that in passing through the drift space the beam is of a diameter substantially equal to the diameter of the electrode forming the drift space.

In accordance with a further feature of this invention, the electrodes defining the output space or gap are so constructed and arranged that the beam, after traversing the drift space, is highly concentrated and focused upon 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 an elevational view of an electron discharge device illustrative of one embodiment of this invention;

Fig. 2 is a detail view in section of the electrode system included in the device illustrated in Fig. 1, showing the configuration and relation of the electrodes therein;

Fig. 3 is a circuit diagram illustrating one manner in which the device shown in Fig. 1 may be operated; and

Figs. 4 and 5 are detail views in section showing the form and relation of electrodes in other illustrative embodiments of this invention.

Referring now to the drawing, the electron discharge device shown in Fig. 1 comprises an elongated evacuated enclosing vessel 10 having at the ends thereof inwardly extending stems 11 and 12 from one, 11, of which there is supported, by leading-in conductors 13, a collector electrode 14, and from the other, 12, of which there is supported an electron gun 15. The electron gun, which produces a concentrated beam of electrons projected along and in the direction of the longitudinal axis of the enclosing vessel 10, may be of any one of a number of constructions such, for example, as those disclosed in Patent 2,268,165, granted December 30, 1941, to Carlyle V. Parker and Arthur L. Samuel, and Patent 2,308,800, granted January 19, 1943, to Alva Eugene Anderson. It comprises generally, as shown in Fig. 3,

a cathode 15a, for example of the indirectly heated type, and a pair of centrally apertured electrodes 15b and 15c coaxial with the cathode.

Between the electron gun 15 and the collector electrode 14 and in coaxial relation therewith is an electrode system including a pair of electrodes 16 and 17 defining an input gap 18, a second pair of electrodes 19 and 20 defining an output gap 21 and an intermediate electrode 22 defining a section of a drift space 23, each of these electrodes including an annular disc portion 24, projecting through and hermetically sealed to the wall of the enclosing vessel 10. As shown clearly in Fig. 2, the electrodes 16 and 19 include central cylindrical portions 25 and 28 respectively extending toward the electron gun 15 and collector electrode 14 respectively, and the electrodes 17 and 20 include frusto-conoidal or trumpet-shaped portions 26 and 27 respectively flaring in opposite directions and extending from immediately adjacent the drift space electrode 22.

During operation of the device, as illustrated in Fig. 3, the electrode 15b may be connected directly to the cathode and the electrode 15c may be maintained at a positive potential, for example of the order of 300 volts, with respect to the cathode, as by a battery 29 connected across a suitable resistance 30, so that the electrons emanating from the cathode are concentrated into a beam and accelerated toward the input gap 18. The electrodes 16 and 17 defining the input gap 18 and the electrodes 19 and 20 defining the output gap 21 are connected by resonant circuits 31 and 32 respectively, which may be in the form of cavity resonators such as described in Patent 2,281,717, granted May 5, 1942, to Arthur L. Samuel, the several electrodes being biased at positive potentials, for example of the order of 1500 volts, with respect to the cathode 15a as by batteries 33. The circuit 31 may be energized by a coil 34 coupled thereto. The collector electrode 14 is maintained at a potential somewhat higher than that of the electrode 15c.

The drift space electrode 22 is connected to the resistance 30 as shown and is maintained at a low potential, for example of the order of 20 volts, with respect to the cathode 15a so that there is produced in the drift space 23 a retarding field into which the velocity varied beam issuing from the gap 18 is projected. In this drift space, which extends from the input gap to the output gap, the faster moving electrons in the beam overtake the slower moving electrons so that a periodic bunching of the electrons results and the velocity variations are thus converted into density variations. The density varied beam then flows through the output gap 21 and excites the resonant circuit 32 associated therewith.

The establishment of a retarding field in the drift space, it has been found, aids the electron bunching effect therein so that a high percentage density variation is obtained. Furthermore, such field enables the use of a short drift space and a low voltage electrode structure. In addition it will be noted that because of the form of the portion 26 of the electrode 17, the electron beam, in flowing through this electrode, diverges and enters the region 23 bounded by the drift space electrode 22 with a diameter substantially equal to the diameter of the electrode 22. Hence, space charge effects are reduced and a uniformity of interaction between the electrons constituting the beam and the drift space field is realized.

The drift space, therefore, is highly efficient and enables the attainment of high transconduct-

ances. The gain of the device, it will be appreciated, may be controlled by varying the potential of the electrode 22.

The electrons leaving the drift space constitute a density varied beam which is accelerated toward the output gap 21 and, because of the form of the portion 27 of the electrode 20 and because of the electrostatic lens action produced by the potentials applied to electrodes 17, 22 and 20, is concentrated and sharply focused upon the output gap 21.

Although in the embodiment of the invention illustrated in Figs. 1 and 2 the drift space electrode is of curved radial section with its convex surface toward the longitudinal axis of the electrode system, it may be of other forms two of which are illustrated in Figs. 4 and 5. In the form shown in Fig. 4, the drift space electrode 22 includes a central cylindrical portion 35 and in the form shown in Fig. 5, the central portion of the drift space electrode 22 is curved in longitudinal section with the concave surface toward the axis of the electrode system. Also, as shown in Figs. 4 and 5, the central portions of the electrodes 16 and 19 may be frusto-conical, the smaller end thereof being toward the gap defining electrode associated therewith.

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 pair of electrodes having juxtaposed aligned apertured portions defining an input gap, means opposite one end of said input gap for projecting an electron stream thereinto, means opposite and spaced from the other end of said input gap defining an output gap, said output gap defining means including an apertured electrode in alignment with said input gap and including also a second electrode mounted behind said apertured electrode relative to said input gap, said input and output gaps being separated by a drift space, and means for producing a retarding field in said drift space, said retarding field producing means comprising a hollow electrode in said drift space and in alignment with said input and output gaps and having its ends in juxtaposition to said first apertured electrode and to the electrode of said pair of electrodes toward said output gap, and the internal transverse dimensions of said hollow electrode being substantially greater than the transverse dimensions of said input gap.

2. Electron discharge apparatus comprising a first means for producing a concentrated electron beam, a second means opposite said first means for velocity varying said beam and causing divergence thereof, means opposite said second means defining a drift space region into which the diverged beam is projected, and an output means beyond said drift space region, said output means including a pair of electrodes defining an output gap, one of said electrodes having a hollow portion extending from said drift space region and converging toward said output gap.

3. Electron discharge apparatus comprising an electron gun for producing a concentrated electron beam, said gun including a cathode and an accelerating anode, means for velocity varying said beam including a pair of electrodes in spaced

5

coaxial relation with said gun and defining an input gap, the electrode of said pair furthest from said gun including a hollow portion flaring away from said gun, means for producing a retarding field in a region adjacent the larger end of said hollow portion including an electrode opposite the larger end of said flaring portion and having a tubular portion the diameter of the end of which toward the larger end of said flaring portion is of substantially the same diameter as said larger end, and an output means opposite said last-mentioned electrode.

4. Electron discharge apparatus in accordance with claim 3 wherein said output means comprises a pair of spaced coaxial electrodes defining an output gap and one of which electrodes includes a hollow portion extending from immediately adjacent said tubular portion and converging away therefrom.

5. An electron discharge device of the velocity variation type comprising a pair of spaced elec-

6

trodes having aligned apertured portions, a first frusto-conical electrode between said pair of electrodes and having its smaller end in juxtaposition to, in alignment with and defining an input gap with the apertured portion of one of said pair of electrodes, a second frusto-conical electrode between said first frusto-conical electrode and the other of said pair of electrodes, said second frusto-conical electrode having its smaller end in juxtaposition to, in alignment with and defining an output gap with the apertured portion of said other of said pair of electrodes, a hollow electrode intermediate said frusto-conical electrodes and having its ends in juxtaposition to and of substantially the same diameter as the larger ends of said frusto-conical electrodes, said hollow electrode increasing in diameter from its ends toward its center, and means for projecting an electron stream into said input gap and toward said hollow electrode.

ARTHUR L. SAMUEL.