Dec. 16, 1941. H. E. HOLLMANN 2,266,639

CONCENTRATION-CONTROLLED SECONDARY EMISSION TUBE

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Fig. 1

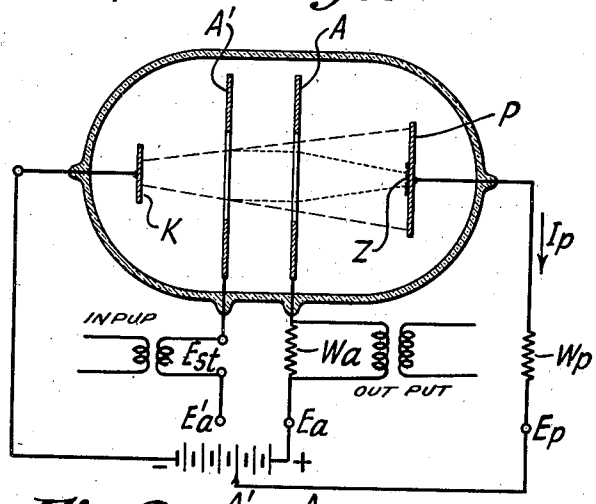


Fig. 1a

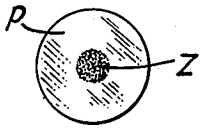


Fig. 2

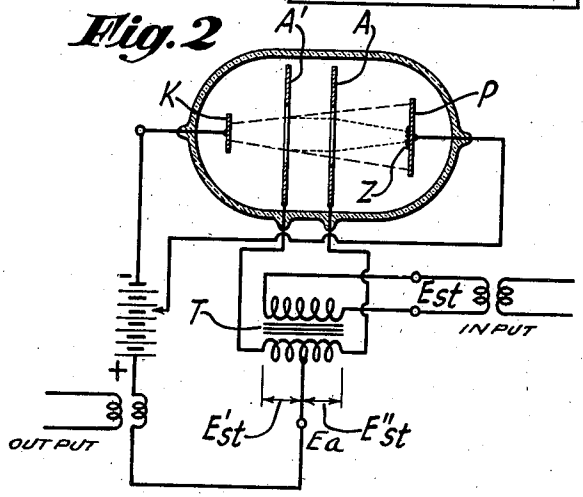


Fig. 3

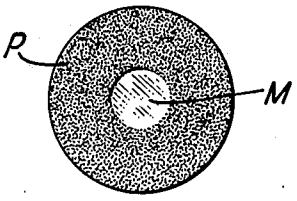


Fig. 4

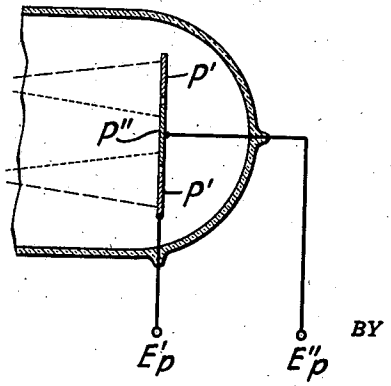
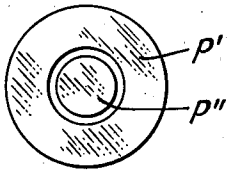


Fig. 4a



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Fig. 5

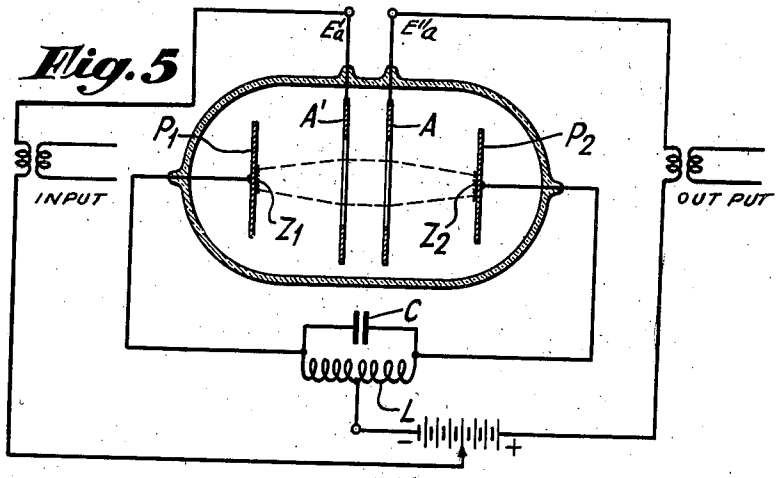


Fig. 6

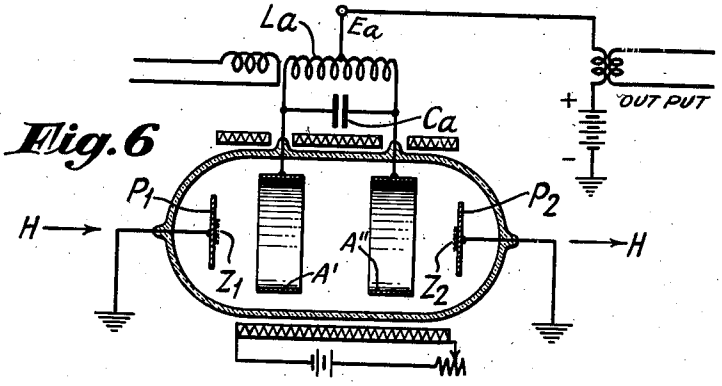
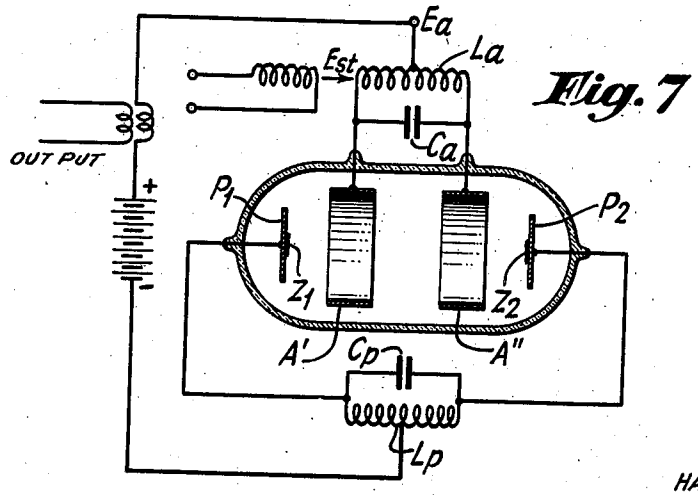


Fig. 7



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Patented Dec. 16, 1941 2,266,639

UNITED STATES PATENT OFFICE

2,266,639

CONCENTRATION-CONTROLLED SECONDARY EMISSION TUBE

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Application January 26, 1939, Serial No. 252,905
In Germany January 28, 1938

7 Claims. (Cl. 250—27)

The present invention relates to an electron discharge tube for producing, rectifying, and amplifying electron currents the output current of which is varied by influencing or controlling the electron-optical concentration of one or more primary electron streams impinging upon a target electrode.

In one method of controlling the output of an electron discharge tube the concentration and the position of the focus of an electron beam is varied by means of an electron-optical lens system. The variation of the concentration or focal distance alone, does not vary the number of the electrons striking a target electrode and the magnitude of the current flowing to it but only the area hit by electrons and, thereby, the specific superficial density of the electron stream on the target electrode. In order to convert these variations of superficial density into current variations the target electrode is provided with a diaphragm through which, depending on the degree of concentration, more or less electrons pass so that behind the diaphragm an electron beam is obtained which upon reaching the target produces current of greater or less magnitude when striking a further target electrode.

In accordance with the present invention, the control of the output of an electron discharge device by concentrating an electron beam or cutting off marginal portions of a beam, is appreciably improved and made more efficient by causing the electron beam, the concentration of which is varied by the controlling action, to impinge on an output or target electrode which has a secondary electron emitting area smaller than the target, such as a spot covered with a material of high secondary electron emissivity. All the primary electrons reach the target electrode independent of the actual concentration of the beam but more secondary electrons are released by the target electrode when more primary electrons impinge upon the treated multiplying spot, i. e. the more sharply the primary electron beam is concentrated on to this spot. Corresponding to the multiplying power of this spot the efficiency of the concentration control described above is enhanced.

For a better understanding of the invention reference may be had to the accompanying drawings in which Figure 1 is a longitudinal section of a tube embodying one form of the invention; Figure 1*a* is a plan view of the target of the tube shown in Figure 1; Figure 2 shows one form of circuit connections for controlling the tube shown in Figure 1; Figure 3 is a plan view of a modified form of target; Figure 4 is a longitudinal section of the target end of a tube having another modified form of target; Figure 4*a* is a plan view of the target of the tube shown in Figure 4; and Figures 5, 6, and 7 are longitudinal sections of forms of electron multipliers having two cathodes and embodying a form of the invention.

The embodiment of the present invention in general form schematically shown in Fig. 1 of the accompanying drawings is a tube in which K designates an appropriate electron source, such as a thermionic or photoelectric cathode. A is an accelerating anode or diaphragm which is maintained at a constant positive high potential and through which the electrons emitted by the cathode K pass all or in the greater part in form of a beam impinging upon a target or intercepting electrode P which is somewhat less positive than the anode A. In order to vary the concentration of the said electron beam at will another diaphragm A′ is located between K and A and supplied with a constant D. C. voltage E'_a. The bias potentials of the anode diaphragm A and the target electrode P are designated by E_a and E_p respectively. The two diaphragms A and A′ form an electron-optical lens system the focal distance of which may be varied within a wide range by a superimposed control voltage E_{st} less than the bias potential of the diaphragm A′. For two distinct limiting values depending on the control voltage E_{st} as well as on the D. C. voltages at the diaphragms A and A′ the electron beam assumes for instance the longitudinal sections drawn in Fig. 1 by interrupted and chain-dotted lines respectively. In the case illustrated by the chain-dotted lines the beam is very diffuse so that the target electrode P is equally hit over almost its entire surface by the primary electrons. In the other case illustrated by the interrupted lines the beam is concentrated so sharply that it is restricted to and its focal point is incident on the centre of the target electrode P.

While the target electrode P should consist as a whole of a material having a secondary electron emissivity as low as possible a part of it, in the case of Fig. 1 the central portion Z, is covered, according to the present invention, with a material having high secondary electron emissivity, for instance barium oxide or cesium oxide. Under the first limiting condition, i. e. with a diffuse beam, only a small percentage of the primary electrons takes part in the secondary electron multiplication, the percentage being deter-

mined by the ratio of the area Z of the secondary emissive layer to the entire area hit by primary electrons while under the second limiting condition, where the beam is sharply concentrated all the primary electrons liberate secondary electrons. As the electron-optical concentration increase the total current I_p flowing off through the target electrode P decreases so that voltage variations proportionate to the control voltage E_{st} are obtained across an appropriate output resistance W_p connected to the target electrode P. It should be borne in mind that the directions of flow of the secondary electrons and of the primary electron stream are opposite. If the beam of primary electrons is more sharply concentrated on the secondary emissive central area Z the number of secondary electrons is increased and the current I_p consisting of the difference between the primary electrons and the secondary electrons is reduced.

The secondary electrons released by the area Z pass over to the acceleration anode A which is positive with respect to the target electrode P, so that the current flowing off through the acceleration anode or anode diaphragm A is varied in dependency upon the concentration of the primary electron beam. If an output resistance W_a is inserted in the circuit of the acceleration anode A, the useful output may be taken from either W_a or W_p or from both resistances.

As the diaphragms A' and A are nearly equivalent electrically to one another the control voltage E_{st} may be superimposed on the bias potential E_a of the diaphragm or acceleration anode A instead of on the bias potential E'_a of the diaphragm A'. If desired, a particularly favourable concentration control may be brought about by varying the potential of A' as well as the potential of A, as shown in Fig. 2 wherein two control voltages E'_{st} and E''_{st} are superimposed by means of a push-pull transformer T in phase opposition to the bias potential E_a common to both diaphragms.

The variation of the concentration of the electron beam may be brought about by varying the potential of the target electrode P instead of varying the potentials at the diaphragms A and A' as the electrostatic field existing between A and P also enters into the laws governing the electron-optical lens conditions. If, therefore, the potential of P is varied two different effects are set up. At first, the impact velocity of the primary electrons is varied and, thereby, also the number of secondary electrons released by the central area Z which results, as with the well known dynatron, in the origin of a negative resistance. In the second place, the electron-optical concentration control which is made use of in accordance with the present invention is accompanied therewith. As easily may be proved, by means of a suitable choice of the bias potentials at the diaphragms A and A' and at the target electrode P one may link together the two effects so as to act in the same sense whereby the inherent negative dynatron resistance can be considerably reduced.

If, on the other hand, the reverse dependence of the secondary electron multiplication upon the concentration and, thereby, of the output current upon the control action should be obtained, i. e. if it should be effected that the number of secondary electrons decreases as the concentration of the beam increase one may reverse the distribution of the secondary emissive layer on the target electrode P, for instance by coating this electrode along its entire surface and recessing only a central zone M to provide an appropriate area of low secondary electron emissivity, as shown in Fig. 3.

It is obvious that any desired rising or falling characteristics are obtainable depending on the respective utilization of the tube. The primary electron stream need not be concentrated along two dimensions as a disc-like or ribbon-shaped flat electron beam may be used, provided the shape of the highly secondary emissive zone of the target electrode corresponds to the cross section of the beam.

The further development of the practical possibilities involved in the present invention results in the arrangement shown in Fig. 4 which differs from the above described tubes in that the primary electron current which does not take part in the secondary electron multiplication is separated from the useful current proper. For this purpose the target electrode P is divided according to its non-secondary emissive and secondary emissive zones into two electrodes P' and P'' which are electrically insulated from each other the one of which P'' in the form of a flat ring surrounds and is concentric with the other P' in the form of a disc. Depending on whether the central sheet or disc P' or the surrounding ring P'' is covered with the secondary-emissive layer the one or the other part may serve as output electrode while the electron current incident upon the other part leaks away.

The characteristics obtained with the tubes described so far, both the falling and the rising ones, are valid from stationary operating conditions up to so high frequencies that the transition time of the electrons governs or impairs the performance of the tube.

In Fig. 5 there is shown a tube which is operative only within the range of ultra-high frequencies and is the result of embodying this invention in a secondary electron multiplier which utilizes alternate release of secondary electrons. As in the well known Farnsworth-tube the acting emission current is completely carried, after a resonant rise or building-up process initiated by photoelectric or thermionic electrons, by secondary electrons alternately released by two oppositely disposed target electrodes P_1 and P_2 the central portions Z_1, Z_2 of which are made secondary emissive. A and A' designate diaphragms like that of Figs. 1 and 2. With the electron-optical control-action of the target electrodes themselves in mind the operation of the arrangement shown in Fig. 5 may be easily understood. The oscillatory circuit L—C connected between the two target electrodes yields the control voltages which not only control the impact velocity of properly phased electrons, as is sufficiently known from the performance of the Farnsworth-tube, but at the same time, according to the present invention, cause by means of the concentration control the improperly phased electrons because of the invergent shape of the beam to surpass the boundaries of the highly secondary emissive multiplying zones Z_1 and Z_2 and not to take part in the secondary electron multiplication.

As only the properly phased electrons are multiplied by means of the present invention a considerable reduction of the idle current and an increase of the efficiency is achieved in comparison with the known Farnsworth-tube operating without concentration control.

It is obvious that in this dynamic concentra-

tion-controlled generator the improvement shown in Fig. 4 in connection with static operating conditions may be used if the oscillatory circuit L—C is connected not to the target electrodes P_1 and P_2 as wholes but only to the secondary emissive spots Z_1 and Z_2 for which purpose the target electrode sheets or plates are to be subdivided, as before, into two concentric electrodes with only one part of each electrode being secondary emissive and connected to the oscillatory circuit while the other parts are supplied with direct voltages only.

As shown in Figure 6, the concentration control may be brought into action on the anode as well as on the target electrodes. The two target electrodes P_1 and P_2 with the secondary emissive zones Z_1 and Z_2 do not carry any high-frequency voltages but instead the two anodes which are shown here as annuli A' and A'' are connected to the excited resonant cicruit L_a—C_a in a similar manner as in Fig. 2 so that the high-frequency control voltage is set up between them. As the frequency of the control voltage E_{st} must be approximately equal to the transit time of the electrons travelling from P_1 to P_2 and vice versa or to a multiple of the same, a separation of the improperly phased electrons from the properly phased ones takes place in accordance with the invention and because of the varying concentration of the beam which improves the excitation and the control conditions. H designates the direction of the constant magnetic field which is used with the Farnsworth-tube.

Finally, the arrangements shown in Figs. 5 and 6 may be combined as shown in Fig. 7. In this way the concentration-controlled generator circuit may be used as an amplifier by impressing the voltage E_{st} to be amplified on to the anode oscillatory circuit L_a—C_a and taking off the amplified voltages from the circuit L_p—C_p connected to the target electrodes P_1, P_2. Suitable operating potentials supposed, the rôles of the both circuits also may be exchanged.

The described examples are sufficient to illustrate and explain the performance of the concentration control according to the present invention under static conditions as well as under ultra-dynamic conditions.

It should be appreciated that the object of the present invention offers also considerable advantages over a tube wherein an electron beam is deflected as a deflection type beam tube requires a sharply concentrated beam the concentration of which must remain the same during the deflection, while the present invention requires neither a concentration of the same extent nor a lateral deflection at all and permits, therefore, higher current intensities.

What I claim as new and desire to secure by Letters Patent is the following:

1. An electron discharge device comprising a pair of opposed electron emitters, a pair of apertured anodes positioned side by side with an unobstructed space between them and interposed between said emitters with coresponding apertures in alignment with said emitters and coaxial with an axis which intersects said emitters, means for biasing both said anodes positive with reference to both said emitters to concentrate an electron discharge between said emitters into a focused electron beam along said axis, an input circuit including said anodes for varying the difference in potential between said anodes to an extent less than the anode bias to vary by electron lens effect the position on said axis of the focus of said beam, and an output circuit including one of said anodes for absorbing power from said discharge, one of said emitters comprising a metal sheet having at the intersection of its surface and said axis a coating of high secondary electron emissivity symmetrically disposed about said intersection and smaller than said sheet and surrounded by uncoated metal.

2. An electron discharge device comprising an evacuated envelope enclosing an electrode assembly comprising a pair of cathodes having oppositely disposed surfaces capable of emitting electrons and transverse to the longitudinal axis of said assembly, one of said surfaces having two zones coaxial with said axis, one of said zones being coated with material capable of emitting secondary electrons at a ratio to impacting electrons greater than unity and the other zone having a surface of bare metal, means for producing a difference of potential between said cathodes, a pair of annular anode electrodes in said enevelope interposed between said cathodes and positioned side by side with unobstructed space between them, each of said anodes having an aperture coaxial with said axis, said anode electrodes constituting an electron lens with an unobstructed path through it, means for biasing both said anode electrodes positive with reference to both said cathodes to form the electron flow between said cathodes and through said anodes into an electron beam focused at a point on said axis, an input circuit including both said anode electrodes for varying the potential of said anode electrodes with reference to each other to an extent less than the biasing voltage to vary by electron lens effect the position along said axis of the focus of said electron beam, and an output circuit including one of said anode electrodes.

3. A device in accordance with claim 2 in which the input circuit including said anode electrodes applies to both anode electrodes, a control voltage in which the voltage on each anode electrode is opposed in phase to the voltage on the other anode electrode.

4. A device in accordance with claim 2 in which the means for varying the potential of said anode electrodes with reference to each other comprises a resonant circuit which connects the anode electrodes and is tuned to the fundamental operating frequency of the device.

5. An electron discharge device comprising an evacuated envelope enclosing a pair of flat oppositely disposed cathodes, each having an inner zone and an outer zone, one of said zones on each cathode having a surface capable of emitting secondary electrons at a ratio to impacting electrons greater than unity and the other zone being substantially non-emitting, a pair of flat annular focusing anodes positioned side by side between said cathodes and coaxial with the center line of the inner zones of said cathode, means for biasing both said positive anodes with reference to the mean potential of said cathodes to concentrate the electron discharge between said cathodes into an electron beam, an input circuit including said focusing anodes for producing a variable difference of potential between said focusing anodes with reference to each other to vary the focus of said beam, means for establishing an alternating potential between said cathodes, and a work circuit including one of said focusing anodes for utilizing the output of said device.

6. A device in accordance with claim 5 in

which each of said cathodes is a metal sheet having coaxial with said annular anodes a portion of the surface facing said anode electrodes coated with material of higher secondary electron emissivity than the remainder of the surface.

7. A device in accordance with claim 5 in which each of said cathodes is a metal sheet having at the center and coaxial with said focusing anodes a circular spot smaller than the sheet and higher secondary electron emissivity than the metal of the sheet.

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