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MULTISTAGE RE-EMISSION AMPLIFIER

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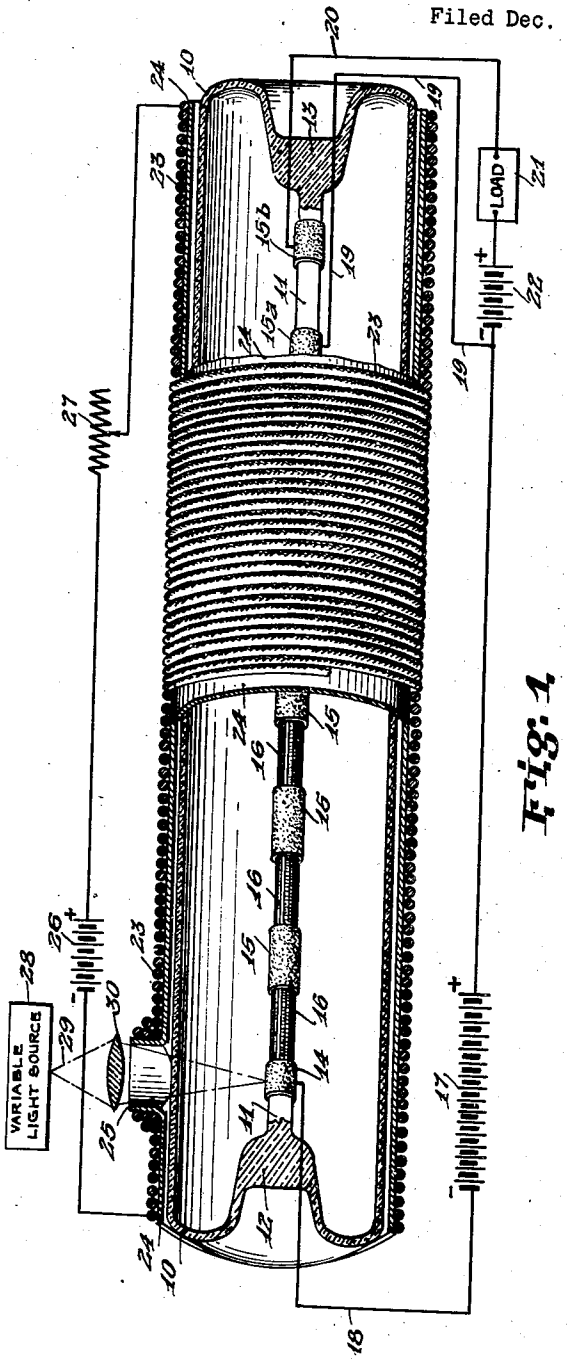


Fig. 1

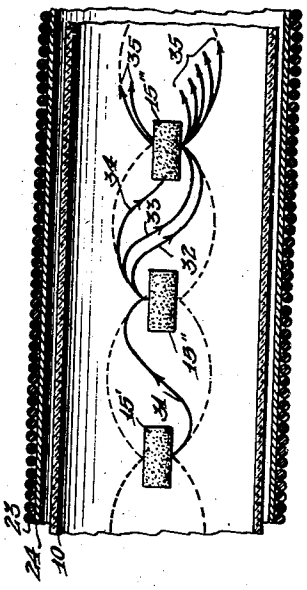


Fig. 3

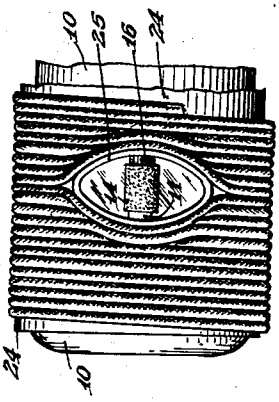


Fig. 2

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MULTISTAGE RE-EMISSION AMPLIFIER

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8 Claims. (Cl. 250—27.5)

This invention relates to electronic amplifier tubes and more particularly to multi-stage amplification utilizing re-emission characteristics within a single envelope.

In order to provide high amplification for weak electrical signals, the conventional amplifier arrangements provide for cascaded stages of ordinary amplifier tubes coupled by impedance elements. In the amplification of photo-electric currents for example, the use of the high resistance coupling between the photo-electric tube and the first amplifier stage introduces extraneous noises to the signal. The ordinary circuit noises due to thermal agitation, shot-effect and the like, limit the signal-to-noise ratio obtainable.

Recent attempts have been made to employ the so-called secondary emission or re-emission characteristics of electronic tubes for relatively noiseless and high gain amplification within a single envelope. The Patent No. 1,903,569 to K. W. Jarvis and R. M. Blair of April 11, 1933 discloses a multi-stage amplifier within a single tube wherein the electrons impinging upon specially prepared electrode surfaces dislodge a correspondingly greater number of secondary electrons, which in turn are directed to the next adjacent electrode for cumulative re-emission amplification. The original signal is accordingly successively amplified by successive dislodgment of increased number of secondary electrons along the multi-electrode path cascaded within the tube.

The elimination of impedance coupling between electronic amplifier stages reduces thermal circuit noises of the amplifier. By arranging a plurality of re-emission amplification stages in series within a common envelope, enormous amplification of weak electrical signals is feasible. The comparatively wide spacing between the electrodes reduces the interelectrode capacitance between them permitting a wider range of frequencies to be amplified by this method as compared to conventional methods.

For the efficient operation of a multi-stage re-emission amplifier, it is necessary to separate the electrons impinging upon an electrode from those dislodged and emitted therefrom. It is also necessary that the electrons due to secondary emission be directed or focused upon the succeeding electrode. The prior art employs electrodes which are flat and arranged in complicated manners to provide the focusing action. I am aware that magnetic fields have been employed in conjunction with the electrostatic fields to direct the re-emitted electrons to the proper target. In my present invention, I provide a novel arrangement of circular electrodes in a simple manner to effect the re-emission amplification hereinbefore set forth. I also arrange a solenoid about the tube to provide an axial constant magnetic field about the electrodes. It is an important feature of my present invention to direct the re-emitted electrons to the next succeeding electrode in a three dimensional cycloidal path having a predetermined pitch equal to the distance between adjacent electrodes as hereinafter described in more detail.

It is accordingly an object of my present invention to provide a novel construction of multi-stage re-emission amplifiers.

It is another object of my invention to provide a novel electron beam focusing arrangement for re-emission amplifiers.

It is a further object of my present invention to provide a novel, cheap, simple and efficient multi-stage re-emission amplifier.

These and other objects of my invention will become apparent in the following description in connection with the drawing in which:

Figure 1 is a partial sectional elevation of a preferred embodiment of a multi-stage re-emission amplifier tube with a schematic circuit diagram employing it.

Figure 2 is a top view of the portion of the tube containing a window to admit light.

Figure 3 is a schematic illustration for describing the electronic action of the tube.

In carrying out my invention, I employ a cylindrical glass envelope 10 having a glass rod 11 secured centrally between the envelope seals 12 and 13. A circular electrode 14 is mounted near one end of the axial post 11. The outside surface of the electrode 14 is coated with a photo-sensitive substance. A plurality of circular electrodes 15 are mounted along the central rod 11 spaced from each other in a predetermined manner.

The electrodes are interconnected by resistances of relatively high value, of the order of 100,000 ohms, to provide electrical continuity between them and to maintain the electrodes at successively higher electrostatic potential levels. In a preferred arrangement, I use a carbon or graphite composition 16 applied around the central tube 11 interconnecting the electrodes. Compositions for such a resistive coating 16 are well known in the art. A direct curent potential source 17 applies the necessary electrostatic potential to the electrodes. The photo-sensitive cathode 14 is connected to the negative side of the battery 17 by connection 18. The next to the last electrode 15a is connected to the positive side of potential source 17 by lead 19. A series circuit is accordingly had from the negative side of battery 17 to photo-sensitive cathode 14 through lead 18, through resistive coatings 16 and electrodes 15 in succession to the electrode 15a and back to the positive side of the battery through lead 19. A small circulating current will flow in this series circuit, and the potential drop across the resistances 16 will cause the electrodes 15 to have corresponding electrostatic differences of potential in a pre-

determined manner. The voltage of the source 17 should be sufficiently high so as to be equal to the sum of the differences in potential between all the cascaded electrodes. The electrostatic difference in potential between the two adjacent electrodes is preferably of the order of 100 to 400 volts.

There is no resistive coating between the last electrode 15b and the next to last electrode 15a. Electrode 15b is connected externally by means of lead 20 to one side of a load circuit or translation device 21. The other side of the load circuit is connected to the positive side of the potential source 22, the negative side of which is connected to the previous electrode 15a by means of lead 19. The voltage of potential source 22 is preferably substantially equal to the voltages between the successive electrodes 15.

The electrodes 15 are specially prepared with a surface particularly adapted for secondary electron emission. Such surfaces are already established in the art and may, for example, be a silver-oxide layer having a further layer of caesium combined therewith. Such a surface is somewhat similar to that used in some types of photo-electric tubes and is accordingly photo-sensitive also. Such a surface will easily release electrons when impinged by primary electrons, the ratio of the secondary or re-emitted electrons to the primary electrons being dependent upon the velocity of the primary electron at impact. An emission ratio of five, for example, means that five secondary electrons will be dislodged or emitted from the electrodes 15 for each primary electron impinging thereon. The glass envelope 10 is preferably highly evacuated. The surface of the glass is preferably darkened to prevent extraneous light from reaching the electrodes. A transparent opening is arranged above the photo-sensitive electrode 14 so that light may be focused upon it.

The solenoid 23 wound on an insulation form 24 encloses the cylindrical tube 10. The ends of the solenoid 23 project sufficiently beyond the end electrodes 14 and 15b so as to provide a substantially uniform magnetic field within the envelope 10 and between the end electrodes. Solenoid winding 23 is connected to a direct current source 26 in series with a rheostat 27 used to adjust the current therethrough. A predetermined magnetic field accordingly is adjustable about the electrodes of the multi-stage re-emission amplifier according to my invention. This magnetic field has a uniform intensity across the tube section perpendicular to its axis, as well as axially along the tube. This magnetic field, as will be hereinafter described in detail, is the principal electron beam focusing agent and is the basis of my present invention.

An oval window 25 in the insulated coil form 24 is arranged above the photo-sensitive electrode 14 as illustrated in Figure 2. The window construction permits the light to be directed upon the electrode 14 in order to provide the signal energy which is to be amplified by the tube. I have illustrated a variable light source 28 in Figure 1 which emits a light signal 29 to schematically represent any signal light source which is to be amplified as corresponding electrical signal energy. A lens system 30 focuses the light signal 29 upon the photo-sensitive cathode 14.

The variable light source 28 may, for example, be facsimile signals which would ordinarily be directed to the photoelectric tube of ordinary equipment. Electrons will be emitted from the cathode 14 and be attracted to the electrode 15 which may, for example be at a potential of 200 volts higher than the electrode 14. The magnetic field is effective around the electrodes and in a direction parallel to the axis of the tube. This magnetic field is substantially uniform across the section of the tube as well as axially. The strength of the magnetic field and its polarity is arranged so as to act upon the emitted electrons to focus them or otherwise direct them to the next succeeding electrode 15. The electrons impinging upon the succeeding electrode 15 will in turn act as primary electrons and will dislodge corresponding secondary electrons greater in number by the emission ratio. These re-emitted secondary electrons will in turn be directed to the next succeeding electrode in a similar manner.

In Figure 3, I have schematically illustrated the action which is characteristic of the re-emission amplifier according to my invention. When the electrode 15' emits an electron it will travel to the next succeeding electrode 15'' along a three-dimensional or space curve 31. The path of the curve 31 is determined by the electrostatic difference of potential between the adjacent electrodes 15' and 15'', the strength of the magnetic field surrounding these electrodes and the initial direction of the emitted electron. The path 31 is fundamentally cycloidal in character but also has a helical or spiral component since the operation is not in a single plane but extends around the tube. The distance between the points from which the electron leaves one electrode and at which it impinges upon the next succeeding electrode, I shall term the pitch of the space curve traversed.

The pitch of the space curve is definitely related to the strength of the magnetic field and to the axial component of the velocity of the electrons, which in turn depends upon the voltage between the successive electrodes. The radial amplitude of the space curve depends upon the angle at which the individual electron is dislodged or emitted from the electrode surface. The magnetic field produces the focusing energy which results in the emitted or secondary electrons to be focused upon the next succeeding electrode since it imparts to the radially directed electrons the proper velocity components to cause it to be focused upon the succeeding electrode.

The electron travelling along path 31 will therefore impinge upon the electrode 15'' at a velocity sufficient to dislodge several secondary electrons which will travel in paths 32, 33 and 34. I have illustrated in Figure 3, three such re-emitted electrons for simplicity. These electrons travel in a spiraled cycloidal path to the next succeeding electrode 15'''. These electrons do not travel over a common path since, in general, their directions of emission are not the same. However, the character of their path and their pitch or distance of axial movement are predetermined to cause them to impinge upon the next electrode 15'''. Each impinging electron will in turn act as a primary electron upon the electrode 15''' and in turn cause a number of secondary electrons to be emitted due to its impact. I have illustrated a plurality of individual paths 35 of such electrons emitted from the electrode 15''' which in turn are directed to the next succeeding electrode (not shown) to repeat the action.

It will be obvious that for each electron emitted at the initial electrode 14, a corresponding increased number of electrons will result at the

final electrode of the series arrangement. The ratio of the final number of electrons to the initial emitted electrons of the primary emitter, namely electrode 14, depends upon the number of stages employed as well as the operating parameters used. When a strong light signal impinges upon the photosensitive surface 14, a correspondingly larger number of electrons are initially emitted therefrom, producing an increased output current proportional thereto. The action of the multi-stage re-emission amplifier is linear and the output current through the load or translation device 21 will correspond to the light variations upon the photosensitive cathode 14.

The multi-stage amplifier, according to my invention, will equally amplify direct current as well as alternating currents of extremely high frequency. The low inter-electrode capacitances between the electrodes makes it possible to uniformly amplify extremely wide frequency bands. The elimination of the coupling means of ordinary amplifier arrangements reduces considerably thermal and other circuit noises to produce a signal-to-noise ratio considerably higher than that obtainable heretofore. Extremely high amplification is feasible utilizing only one multi-stage tube as illustrated. By employing a surface of low work function for the anode electrodes so that a relatively larger number of secondary electrons are emitted for each primary impinging electron, and by employing electron velocities to cause a higher ratio of such emission, the cumulative action of the re-emitted electrons will result in an extremely high amplification with a practical or nominal number of stages within a single envelope. The constant magnetic field coacting with the progressively increasing electrostatic field along the tube serves to direct the electrons in a positive predetermined manner between adjacent electrodes along a spiraled cycloidic path having the same pitch as the electrode spacing. Although I have illustrated the principle of my invention utilizing a photosensitive primary emitter or electron source, namely, the cathode 14, it will be realized that a thermionic cathode may equally well be employed. In such case the action of the tube may be controlled by suitable inserted grids or latticed electrodes similar to embodiments already established in the art. However, it is possible to modulate the otherwise constant electron stream by inserting a modulation or signal in series with the solenoid 23 circuit. The action of the modulation signal is to change the pitch of the electron paths between the successive electrodes so that a proportionate number of electrons will fall short of or pass beyond the electrodes it ordinarily should impinge, in turn proportionately decreasing the output current in accordance with the modulation.

Although I have described in detail one particular modification of my invention, it will be obvious to those skilled in the art that changes therein are feasible that fall within the broader spirit and scope thereof and I, therefore, do not intend to be limited except as set forth in the appended claims.

I claim:—

1. A multi-stage electronic amplifier tube comprising an elongated glass envelope; a glass rod supported axially in said envelope; a plurality of spaced secondary emissive electrodes of finite length mounted upon said rod; a primary electron emitter mounted at one end of said rod, and resistance means on said rod interconnecting adjacent electrodes.

2. A multi-stage electronic amplifier tube comprising an elongated glass envelope; a glass rod supported axially in said envelope; a plurality of equi-spaced secondary emissive electrodes mounted on said rod; a primary electron emitter mounted at one end of said rod; resistance means coated on said rod connecting adjacent electrodes; and a solenoid wound about said envelope.

3. A multi-stage electronic amplifier tube comprising an elongated glass envelope; a glass rod supported axially in said envelope; a plurality of equi-spaced secondary emissive electrodes mounted on said rod; a photo-sensitive cathode mounted on one end of said rod; resistance means on said rod connecting adjacent electrodes; and a solenoid wound about said envelope.

4. A multi-stage electronic amplifier tube comprising an elongated glass envelope; a glass rod supported axially in said envelope; a plurality of equi-spaced secondary emissive electrodes mounted on said rod; a photo-sensitive cathode mounted at one end of said rod; resistance means on said rod connecting adjacent electrodes; a solenoid wound about said envelope; and a window in said solenoid for admitting light signals to said photo-sensitive cathode.

5. A multi-stage electronic amplifier tube comprising an elongated glass envelope; a glass rod supported axially in said envelope; a plurality of equi-spaced secondary emissive electrodes mounted on said rod; a primary electron emitter mounted at one end of said rod; resistance means coated on said rod connecting adjacent electrodes; a solenoid wound about said envelope; the last two adjacent electrodes having output terminals for the amplifier.

6. A multi-stage electronic amplifier tube comprising an envelope housing a primary electron emitting electrode, a plurality of spaced secondary emissive electrodes, means for producing a magnetic field longitudinally of said electrodes to form a spiraled cycloidal path for electrons between successive electrodes, said secondary emissive electrodes being located at the focal points of said spiraled cycloidal electron path.

7. A multi-stage electronic amplifier tube comprising an envelope housing a primary electron emitting electrode, a rod mounted within said tube, a plurality of spaced secondary emissive electrodes mounted on said rod, means for producing a magnetic field longitudinally of said electrodes to form a spiraled cycloidal path for electrons between successive electrodes, said secondary emissive electrodes being located at the focal points of said spiraled cycloidal electron path.

8. A multi-stage electronic amplifier tube comprising an elongated envelope housing a photo-emissive electrode, an insulation rod mounted axially within said tube, a plurality of spaced cylindrical secondary emissive electrodes mounted concentrically on said rod, a resistive coating on said rod intermediate and connecting adjacent electrodes, means for producing a magnetic field longitudinally of said electrodes to form a spiraled cycloidal path for electrons between successive electrodes, said secondary emissive electrodes being located at the focal points of said spiraled cycloidal electron path.

WILLIAM G. H. FINCH.