

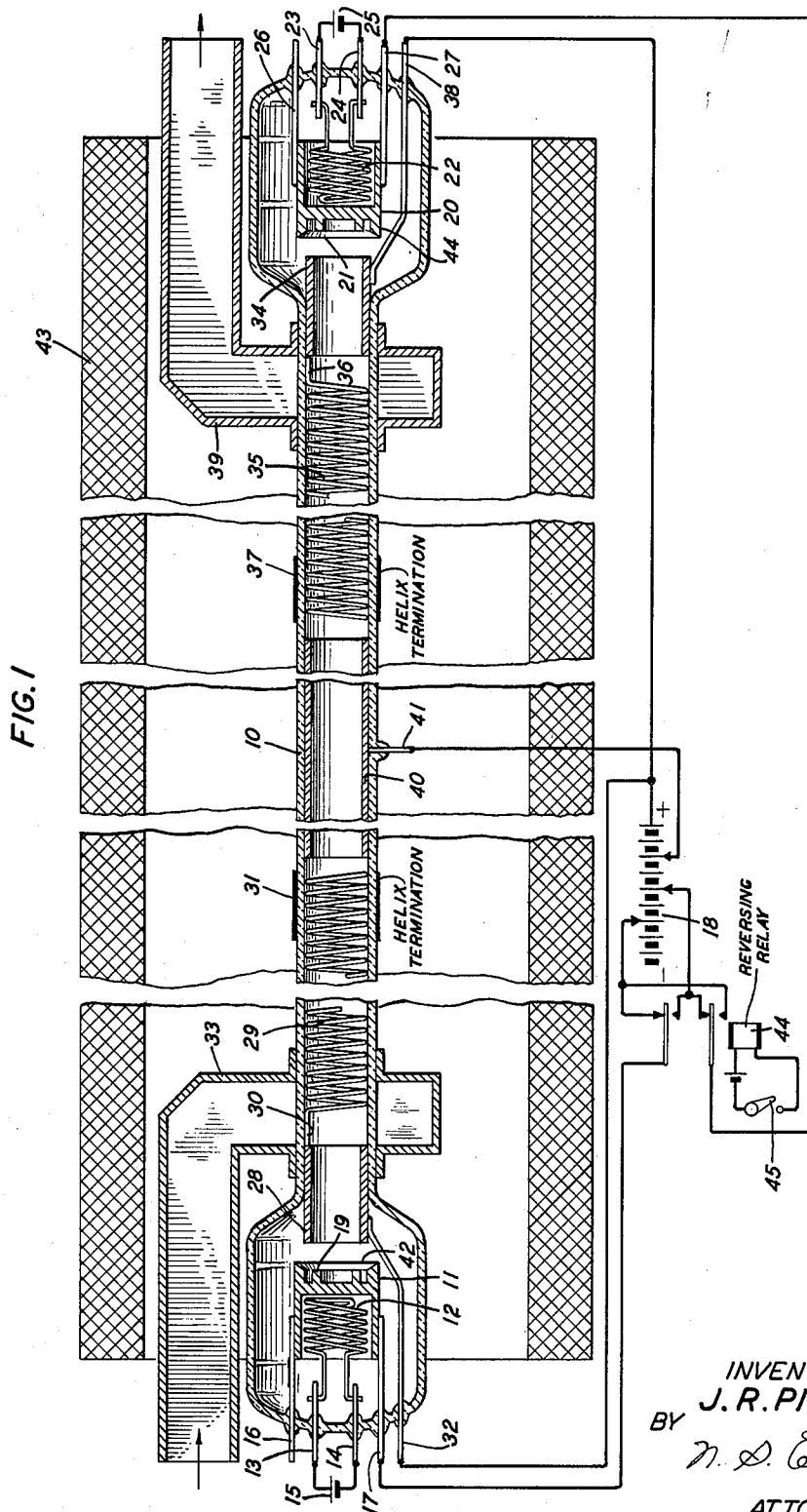
Jan. 10, 1956

J. R. PIERCE
MICROWAVE AMPLIFIER

2,730,647

Filed June 22, 1949

2 Sheets-Sheet 1



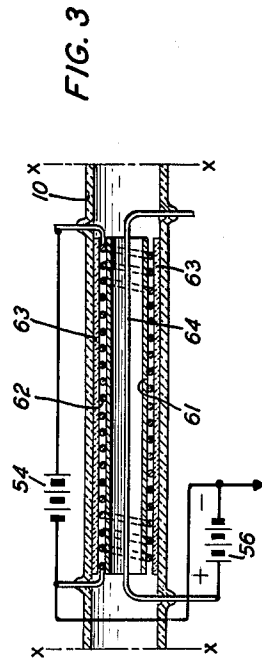
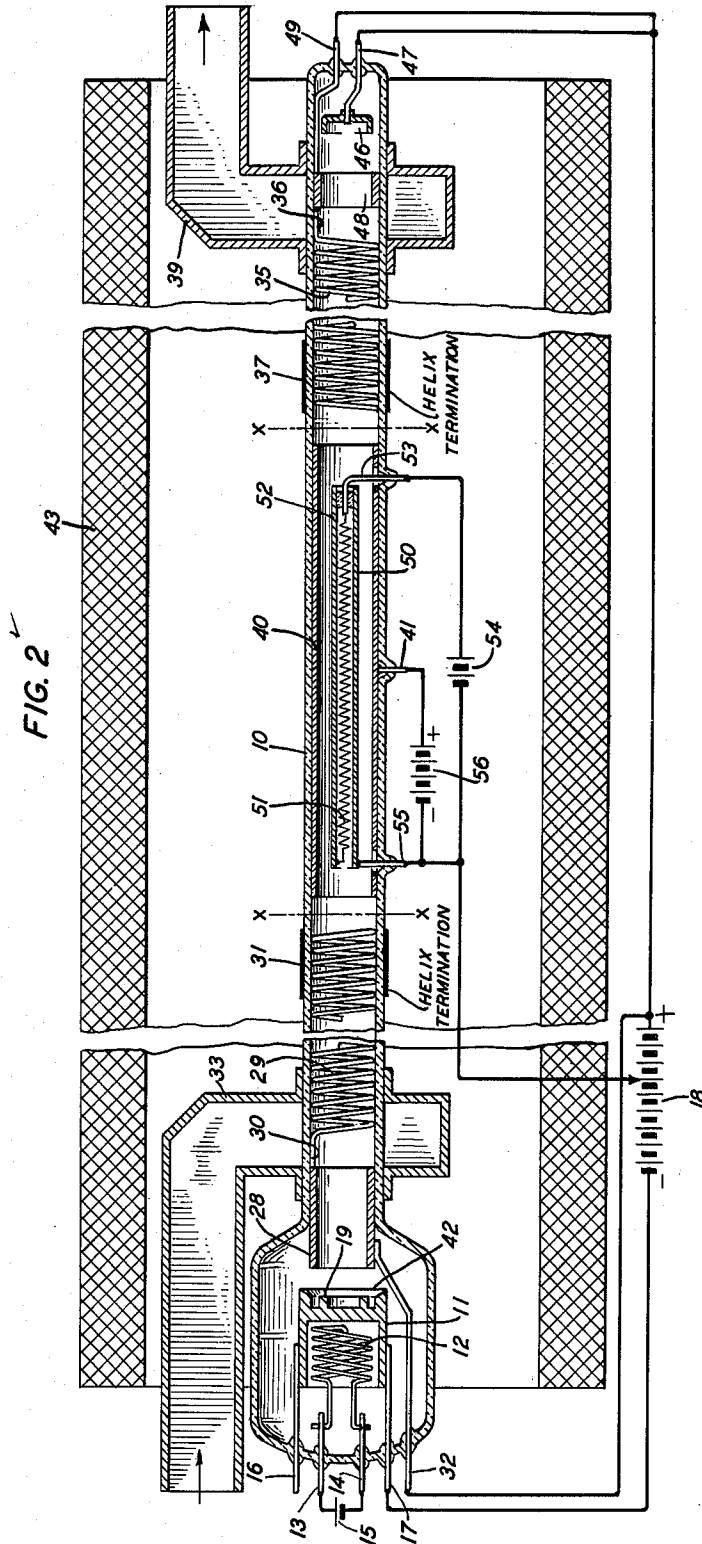
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2 Sheets-Sheet 2



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MICROWAVE AMPLIFIER

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16 Claims. (Cl. 315—3)

This invention relates to high frequency amplifying devices which utilize electromechanical interaction between two groups of charged particles to secure gain. Amplifiers of this general type are disclosed in the application of W. B. Hebenstreit and J. R. Pierce, Serial No. 38,928, filed July 15, 1948.

One object of the invention is to increase the gain of a double-stream amplifier by intermingling the two groups of charged particles as completely as possible.

Another object is to increase gain by increasing the density of the charged particles in the interacting region.

A further object is to produce as great a charged particle density as possible without drawing a large amount of current from a supply source.

A still further object of the invention is to enable a double-stream amplifier to amplify in either direction.

In previous double-stream amplifiers, a pair of closely coupled streams of charged particles (e. g., electrons) are projected along a predetermined path in the same direction at respective different velocities. At the beginning of the path at least one stream is modulated under the control of a signal which is to be amplified. As pointed out in the above-noted Hebenstreit-Pierce application, electro-mechanical interaction between the charged particles of the respective streams causes the impressed variations to grow in amplitude and amplified signal energy is withdrawn at the end of the path. Gain is dependent to a large degree upon the closeness of the coupling between the two streams, being maximum when the charged particles of the two streams are completely intermingled.

In accordance with the present invention, a stream of charged particles from one source is projected in a predetermined direction to interact with charged particles from another source traveling in a different direction. Disturbances impressed upon the stream of charged particles emanating from the first source are amplified by energy interchanges between the charged particles from the respective sources while such particles are traveling in different directions. It has been found that it is possible to achieve greater intermingling of the charged particles of different groups with less difficulty when the particles are traveling in different directions than when they travel in the same direction. Gain is, therefore, correspondingly enhanced. Certain embodiments of the invention have the additional advantage of enabling a greater density of charged particles to exist in the interacting region than would be practical in a conventional double-stream amplifier without drawing increased current from a supply source. Other embodiments have the additional advantage of allowing the direction of amplification to be reversed by a simple reversal of the direct-current potentials of the respective charged particle sources.

A more thorough understanding of the invention will be attained from a study of the following detailed description of several specific embodiments and an inspection of the accompanying drawings, in which:

Fig. 1 illustrates an amplifier utilizing the interaction

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between a pair of oppositely directed electron streams to secure gain;

Fig. 2 shows an amplifier which makes use of a group of electrons moving substantially at right angles to a signal-bearing electron stream to secure gain; and

Fig. 3 represents alternative means for causing electrons to move substantially at right angles to the signal-bearing stream and may be applied to the amplifier of Fig. 2 along the lines X—X.

Referring particularly to Fig. 1, the embodiment of the invention shown makes use of two oppositely directed electron streams. Most of the structure is enclosed by an elongated cylindrical glass vacuum envelope 10. Envelope 10 is enlarged somewhat at either end to accommodate electron emissive structures.

Within the enlarged portion at the left-hand end of envelope 10 is a thermionic cathode 11. Cathode 11 is a short metal cylinder and is axially aligned with envelope 10. Its left-hand portion is hollow and contains a heating coil 12 which is connected by a pair of leads 13 and 14 across a battery 15. Leads 13 and 14 pass through the left-hand end of envelope 10 and hold coiled heater 12 in place. Cathode 11 is held in place by a pair of leads 16 and 17 which are attached at diametrically opposite points on its outer surface and extend through the left-hand end of glass envelope 10. Lead 17 is connected to a movable tap on a main supply battery 18. The right-hand face of cathode 11 has a raised annular emitting portion 19 which is coated with electron-emissive material to emit a tubular beam of electrons when heated.

At the opposite end of envelope 10, within the enlarged portion, is a similar cathode 20 with an annular coated raised emitting portion 21 facing to the left. Cathode 20 contains a heating coil 22 which is connected by a pair of leads 23 and 24 to a battery 25. Heater 22 is supported within cathode 20 by leads 23 and 24, which pass through the right-hand end of envelope 10. Cathode 20 is supported by a pair of leads 26 and 27 which also pass through the right-hand end of glass envelope 10 and which are attached to diametrically opposite points on the outside surface of cathode 20. Lead 27 is connected to a movable tap on supply battery 18.

A short tubular metal electrode 28 is axially aligned with and supported by glass envelope 10 and is located just to the right of cathode 11. A short wire helix 29 is located to the right of electrode 28 and is also supported by glass envelope 10. Helix 29 is connected to electrode 28 by a short straight conductor 30 and its right-hand end is terminated in its characteristic impedance by power dissipative or "lossy" material 31 (e. g., a thin coating of colloidal graphite) on the outside surface of envelope 10. "Lossy" material 31 begins at the right-hand end of helix 29 and extends to the left for approximately a quarter of its length. The "lossy" coating 31 may be made lighter toward its left-hand end in order to give a gradual terminating effect and prevent reflections. A lead 32 is attached to electrode 28, passes through the left-hand end of envelope 10, and is connected to the most positive terminal of battery 18.

An input wave guide 33 is coupled to helix 29 by straight conductor 30. Envelope 10 passes through wave guide 33 substantially normal to its broad surfaces, with the inside surface of the left-hand wall of wave guide 33 flush with the right-hand end of electrode 28. Straight coupling conductor 30 extends for about half the width of guide 33. One end of wave guide 33 is closed and the other may be connected to an input signal source.

The right-hand end of envelope 10 contains elements substantially similar to those included at the above-described left-hand end. A short tubular electrode 34, corresponding to electrode 28, is located just to the left of cathode 20 and a short wire helix 35, corresponding

to helix 29, is situated to the left of electrode 28. Both electrode 34 and helix 35 are supported by glass envelope 10 and they are connected by a short straight section 36. Helix 35 is terminated in its characteristic impedance at its left-hand end by "lossy" material 37 on the outside surface of envelope 10. The distribution of "lossy" material 37 is similar and complementary to that of "lossy" material 31 at the left-hand end of helix 29. A lead 38 is attached to electrode 34 and is connected, after passing through the right-hand end of envelope 10, to the most positive pole of battery 18.

An output wave guide 39 corresponds to input wave guide 33 and is coupled to helix 35 by straight section 36. Envelope 10 passes through wave guide 39 substantially normal to its broad surfaces. The inside surface of the right-hand wall of guide 39 is flush with the left-hand end of electrode 34. One end of wave guide 39 is closed and the other may be coupled to a load.

An elongated tubular metal electrode 40 occupies most of the space between the right-hand end of helix 29 and the left-hand end of helix 35. Electrode 40 is at least several wavelengths long at signal frequencies and has an outside diameter substantially equal to the inside diameter of envelope 10. It serves to shield the main electron interaction region of the amplifier from external effects and to determine the potential of that region. Electrode 40 is supported by glass envelope 10 and is spaced slightly from helices 29 and 35. At an intermediate point, electrode 40 is attached to a lead 41 which passes through the wall of glass envelope 10 and is connected to a movable tap on battery 18.

Electrode 40 is made positive with respect to cathodes 11 and 20 by appropriate settings of the variable taps on battery 18 and cathode 11 is made negative with respect to cathode 20. When cathode 11 is heated, raised portion 19 emits a tubular stream of electrons which are accelerated to the right by electrode 28. The electrons travel to the right within envelope 10 and are eventually collected by cathode 20. The stream is focused by an additional annular raised portion 42 which surrounds raised portion 19 on the right-hand side of cathode 11 and by the longitudinal magnetic field established by a solenoid 43 which surrounds and is concentric with envelope 10. Solenoid 43 is supplied with direct-current from an appropriate source (not shown).

When cathode 20 is heated, raised portion 21 emits a tubular stream to the left. The electrons are accelerated by electrode 34, pass through helix 35 and electrode 40, and are largely collected by helix 29 and electrode 28. The stream is focused by the field set up by solenoid 43 and by an additional annular raised portion 44 which surrounds raised portion 21 on the left-hand end of cathode 20.

When an input signal is applied to wave guide 33, it is transferred to helix 29, which serves to couple the signal to the electron stream. Helix 29 is wound with a pitch such that the wave which travels along it travels at approximately the same velocity as the electrons emitted from cathode 11. The stream traveling to the right is density-modulated by interaction with the field established by the signal as it is transmitted along helix 29. The electrons traveling to the left interact electromechanically with those traveling to the right, causing the variations impressed upon the stream of the latter electrons to grow in amplitude. The stream of electrons traveling to the right may thus be said to support a space charge wave of negative attenuation.

As explained in the above-identified copending Hebenstreit-Pierce application, double-stream gain of this type is characterized by electromechanical rather than electromagnetic coupling between the two streams of electrons. Electromechanical coupling involves direct interaction between the streams themselves rather than by way of electromagnetic fields in or around a nearby conductor or resonator. A typical characteristic of elec-

tromagnetic coupling by way of a conductor or resonator is that approximately the same amount of stored magnetic energy as stored electric energy is involved. In direct electromechanical coupling between two groups of electrons, on the other hand, the magnetic stored energy is much less than the stored electric energy and plays no important role in electromechanical interaction.

The pitch of helix 35 is substantially the same as that of helix 29, enabling the amplified variations to be transferred to helix 35. As the amplified signal energy reaches the right-hand end of helix 35 and straight portion 36, it is transferred to wave guide 39 and is available for application to an appropriate load.

Since the two electron streams are oppositely directed, they are easier to intermingling than they would be if they were like directed. When two like-directed streams are intermingled, they are projected from different cathodes and mechanical difficulties make complete intermingling difficult to obtain. The two cathodes emitting like-directed streams are usually placed in a side-by-side, a concentric, or a tandem relationship. In the first two, intermingling is partial even at best; in the last, one stream may be projected through apertures in the other cathode, but the intermingling is still far from complete. In Fig. 1, the streams are oppositely directed, and cathodes 11 and 20 are located at opposite ends of the electron path, where they do not interfere with electron intermingling. Coupling between streams is greatest when the two streams of a double-stream amplifier are completely intermingled. Therefore, since the oppositely directed streams may be more completely intermingled than like-directed streams, coupling, and hence gain, is correspondingly increased.

In general, amplification will take place when the oppositely directed streams travel at different velocities and/or have different charge densities. Gain may be adjusted and optimized at any particular frequency of operation by adjusting the variable taps on battery 18. For certain frequency ranges, if the charge densities are equal, optimum gain will occur when the faster stream is traveling to the right; for others, when the faster stream is traveling to the left. The electrons from cathode 20 can be made faster or slower than those from cathode 11 by making cathode 20 negative or positive, respectively, with respect to cathode 11. If it is desired to vary the respective stream charge densities in addition to or instead of the stream velocities, the heater voltages supplied by batteries 15 and 25 may be adjusted.

The tube shown in Fig. 1 has the additional advantage of being able to amplify in either direction. For example, if the relative potentials of cathode 1 and cathode 20 are reversed by appropriate adjustment of the variable taps on battery 18, the tube will amplify from right to left rather than from left to right. Wave guide 39 will become the input guide and wave guide 33 the output guide. The reversing may be accomplished, for example, by means of a relay 44 and a switch 45. When switch 45 is open, relay 44 is not actuated and cathodes 11 and 20 are connected as previously described. When switch 45 is closed, relay 44 is actuated and the respective connections from cathodes 11 and 20 to supply source 18 are reversed.

Fig. 2 shows a modification of the double-stream amplifier of Fig. 1 in which electrons are projected in an interacting relationship with, but substantially at right angles to, the electron stream bearing the input signal. As in Fig. 1, most of the structure is enclosed by an elongated cylindrical glass vacuum envelope 10, the left-hand end of which is enlarged to accommodate an electron-emissive structure.

The cathode structure at the left-hand end of envelope 10 is substantially the same as described in connection with Fig. 1, and an input wave guide 33 is similarly coupled to an input helix 29. There is no cathode, however, at the right-hand end of envelope 10. Rather, the electrons emanating from cathode 11 are collected by a

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collector electrode 46. Collector 46 is a flat metal plate with a raised edge projecting slightly to the left and is substantially perpendicular to the axis of envelope 10 at its right-hand end. Collector 46 is supported by a lead 47 which extends through the right-hand end of envelope 10 and is connected to the positive terminal of a main direct-current supply source 18. Cathode 11, which is located at the left-hand end of envelope 10, is connected to the negative terminal of source 18.

A short tubular metal electrode 48 is located to the left of collector 46 and is supported by envelope 10. Electrode 48 is attached to a lead 49 which passes through the right-hand end of envelope 10 and is connected to the positive pole of direct-current source 18. A short wire output helix 37, corresponding to helix 37 in Fig. 1, is situated to the left of electrode 48 and is connected to electrode 48 by a short straight conductor 36. The left-hand end of helix 37 is terminated by a thin layer of "lossy" material 31 distributed on the outer surface of envelope 10.

Envelope 10 passes through an output wave guide 39 with its axis substantially normal to the broad faces of the guide 39, which corresponds to output wave guide 39 in Fig. 1. Straight conductor 36 couples output helix 35 to wave guide 39. As an alternative to the arrangement of electrode 34 in Fig. 1, the inside surface of the right-hand wall of output wave guide 39 is flush with the right-hand end of electrode 48, and the right-hand end of helix 35 extends to the left-hand wall of wave guide 39. Straight conductor 36 is connected to electrode 48 approximately half way between the broad faces of wave guide 39.

As in Fig. 1, a solenoid 73 surrounds and is concentric with envelope 10 and is supplied with current from an appropriate direct-current source (not shown). Solenoid 43, when energized, sets up a longitudinal magnetic focusing field within envelope 10. Also as in Fig. 1, a tubular metal electrode 40 is located in the space between helices 27 and 35 and is supported by glass envelope 10. The length of electrode 40 is preferably at least several wavelengths in the electron stream emanating from cathode 11. Greater lengths give greater available gain.

When cathode 11 is heated, a tubular stream of electrons is projected to the right, lengthwise of and within envelope 10. The emitted electrons are collected by the collector electrode 46. A signal supplied to input wave guide 33 is transferred to the stream in the manner described in connection with Fig. 1.

The element which produces the second electron stream is a tubular thermionic cathode 50. Cathode 50 is concentrically mounted within envelope 10 and electrode 40 and its outside diameter is slightly less than the inside diameter of the stream of electrons emitted by cathode 11. Cathode 50 extends for most of the length of electrode 40 and has an electron-emissive coating on its outer surface.

Cathode 50 is heated by an internal heating coil 51 which is connected to cathode 50 at its left-hand end. A ceramic bushing 52 is located at the right-hand end of cathode 50. The right-hand end of heating coil 51 is connected to a lead 53 which passes through bushing 52. Lead 53 is taken out through the wall of glass envelope 10 and an opening in electrode 40 and is connected to one side of a heater supply battery 54. Lead 53 also serves to support the right-hand end of cathode 50. The left-hand end of cathode 50 is supported by a lead 55 which passes through the wall of glass envelope 10 and an opening in electrode 40 and which is connected to the other side of heater supply battery 54.

Tubular electrode 40 is held positive with respect to cathode 50 by a battery 56 and serves as an anode. Lead 41, which is attached to electrode 40 and taken out through the wall of glass envelope 10, is connected to the positive pole of battery 56 and the negative pole of battery 56 is connected to lead 55. Finally, lead 55 is con-

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nected to a variable intermediate tap on direct-current source 18.

Cathode 50 is heated by heating coil 51 and emits electrons radially outward towards tubular anode electrode 40, with no axial velocity component. The electrons from cathode 50 may either reach electrode 40 or be turned back by the magnetic field produced by solenoid 43, depending on the strength of this field relative to the voltage of battery 56. In either case, the cloud of electrons from cathode 50 interacts with the electron stream from cathode 11 to produce gain at favorable frequencies. The mechanism of interaction is much the same as in any double stream amplifier in which the longitudinal velocity of one stream of electrons is allowed to approach zero, but with the construction of Fig. 2 a large charge density of electrons with zero longitudinal velocity can be produced. Gain may be optimized at a desired frequency by adjusting the voltage of direct-current source 56, the magnetic field, and the tap on source 18 which controls the potential of cathode 50 with respect to cathode 11.

The electrons projected from cathode 50 travel substantially at right angles to the direction of travel of the electrons emanating from cathode 11. Cathodes 11 and 50 do not interfere with one another, enabling the electron intermingling to be more complete than is practical when two like directed streams are employed. Available gain is, therefore, increased by a corresponding amount.

The voltage of battery 56 may be adjusted relative to the strength of the magnetic focusing field to minimize the electron current flow between cathode 50 and the surrounding tubular anode electrode 40. A high electron density in the interacting region is thereby achieved without necessitating a large power drain on battery 56. Available gain is correspondingly high.

The central cathode 50 and associated positive electrode 40 shown in Fig. 2 may be rearranged as shown in Fig. 3. Here the cathode is a metal tube 61 which is concentrically mounted within envelope 10. The inside diameter of cathode 61 is slightly larger than the outside diameter of the electron stream. The inside surface of tubular cathode 61 is coated with electron-emissive material. A heating element 62 is coiled around the outside of cathode 61 and the assembly is supported from glass envelope 10 by three or more spaced ceramic rods 63. The opposite ends of heating coil 62 are brought out through the wall of glass envelope 10 and connected across the heater supply battery 54. Heating coil 62 is electrically connected to cathode 61 at its left-hand end and is electrically insulated from cathode 61 over the rest of its length by a coating of insulating material on the outside surface of the latter.

An anode 64 comprises a wire extending lengthwise of and concentric with cathode 61. The opposite ends of anode 64 are brought out through the wall of glass envelope 10 for supporting purposes. Anode 64 is held positive with respect to cathode 61 by battery 56, the voltage of which may be adjusted to give optimum gain. Battery 56 is connected between the left-hand ends of heating coil 62 and anode 64 and the negative side of battery 56 is connected to a variable tap on direct-current source 18 of Fig. 2.

The operation of cathode 61 and anode 64 is substantially the same as that of cathode 50 and electrode 40, described in connection with Fig. 2, except that the electrons move radially inward from cathode 61 toward anode 64. As does the arrangement of Fig. 2, this structure gives high electron density in the interacting region along with relatively complete intermingling with the signal-bearing stream. Gain, therefore, is high. In addition, the power drawn from battery 56 is small if the voltage of battery 56 is adjusted to give a small net current flow between cathode 61 and anode 64. The variable tap on battery 18 and the magnetic focusing field may be adjusted for optimum operation.

It is to be understood that the above-described arrangements are illustrative of the application of the principles

of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A high frequency amplifier comprising a first source of charged particles positioned to direct a stream of charged particles along a predetermined path and a second source of charged particles positioned along said path to direct charged particles substantially at right angles to said stream along a substantial portion of said path, the coupling between the charged particles from said first source and the charged particles from said second source along the gain-producing portion of the length of said stream consisting substantially only of electromechanical coupling, whereby a signal supported by said stream is amplified by cumulative interaction along said portion of said path between the charged particles from said first source and the charged particles from said second source.

2. A high frequency amplifier in accordance with claim 1 in which said stream is tubular and said second source is cylindrical and concentric with said stream to project charged particles radially in substantially all directions perpendicular to the axis of said stream.

3. A high frequency amplifier in accordance with claim 1 in which said stream is tubular and said second source is positioned within said stream to project charged particles radially outward in substantially all directions perpendicular to the axis of said stream.

4. A high frequency amplifier in accordance with claim 1 in which said stream is tubular and said second source is cylindrical, concentric with said stream, and located outside of said stream to project charged particles radially inward in substantially all directions perpendicular to the axis of said stream.

5. An amplifying space discharge device which comprises an enclosure defining a path of travel for charged particles, a first charged particle source positioned at one end of said path to direct a tubular stream of charged particles along said path, a charged particle collector positioned at the other end of said path, means responsive to an input signal to modulate said stream, a cylindrical second charged particle source positioned coaxially with said stream at an intermediate point along said path to project charged particles radially in substantially all directions perpendicular to the axis of said stream, the charged particles from said second source being substantially commingled with the charged particles from said first source comprising said stream and the coupling between the charged particles from said first source comprising said stream and the charged particles from said second source along the gain-producing portion of the length of said stream consisting substantially only of electromechanical coupling, whereby the variations impressed upon said stream are increased in amplitude as the charged particles comprising said stream pass those from said second source, and means responsive to variations in said stream for withdrawing amplified signal energy.

6. A space discharge device comprising an enclosure which defines a path of travel for charged particles, a first source of charged particles positioned at one end of said path to direct a stream of charged particles along said path and a second source of charged particles positioned at an intermediate point along said path to produce charged particles in the space through which said stream travels, the charged particles from said second source having a velocity component lengthwise along said path of substantially zero, the length of the region along said path in which the charged particles from said second source exist being at least several wavelengths in said stream, and the coupling between the charged particles of said stream and the charged particles produced by said second source along the gain-producing portion of the length of said stream consisting substantially only

of electromechanical coupling, whereby cumulative interaction between the charged particles of said stream and the charged particles produced by said second source amplifies a signal appearing in said stream.

7. An amplifying space discharge device which comprises means providing a signal wave transmission path, means to convey signal wave energy along said path in a predetermined direction, a source of charged particles, and means to direct charged particles from said source across said path over a major portion of its length in a continuous and cumulative interacting relationship with the conveyed signal wave and in a direction substantially at right angles to said predetermined direction, whereby said signal wave energy is caused to increase as it progresses along said path.

8. An amplifying space discharge device which comprises means providing a path of travel for charged particles, a first source of charged particles positioned at one end of said path to direct a stream of charged particles along the length of said path, means surrounding at least a portion of said path to confine moving charged particles to said path, means at one end of said path to modulate said stream under the control of signal wave energy, a second source of charged particles positioned along said path to supply a cloud of charged particles at an intermediate portion of said path over a distance of at least several signal wavelengths in said stream, the charged particles comprising said cloud having a velocity component lengthwise along said path of substantially zero and the coupling between the charged particles comprising said stream and the charged particles comprising said cloud along the gain-producing portion of the length of said stream consisting substantially only of electromechanical coupling, whereby cumulative interaction between charged particles in said cloud and those in said stream produces gain, and means at the other end of said path to withdraw amplified signal wave energy from said stream.

9. An amplifying space discharge device in accordance with claim 8 in which said means to modulate said stream includes aperiodic coupling means.

10. An amplifying space discharge device in accordance with claim 8 in which said means to withdraw amplified signal wave energy from said stream includes aperiodic coupling means.

11. An amplifying space discharge device which comprises an electron gun and a first collector electrode spaced apart to define a path of travel for electrons, means coupled to said electron gun to direct a stream of electrons from said gun to said first collector, an elongated electron emissive electrode extending lengthwise along said path for a distance of at least several signal wavelengths in said stream, a second collector electrode situated substantially coaxially with said elongated electron emissive electrode and extending over substantially the same portion of said path, means coupled to said elongated electron emissive electrode to direct electrons radially of said stream in substantially all directions perpendicular to the axis thereof from said elongated electron emissive electrode to said second collector, means coupled to said stream between said gun and said elongated electron emissive electrode to supply signal wave energy thereto, and means coupled to said stream between said elongated electron emissive electrode and said first collector to withdraw amplified signal wave energy therefrom.

12. An amplifying space discharge device in accordance with claim 11 in which said elongated electron emissive electrode is located centrally within said stream and said second collector is tubular and is located outside of said stream surrounding said elongated electron emissive electrode.

13. An amplifying space discharge device in accordance with claim 11 in which said second collector is located centrally within said stream and said elongated

electron emissive electrode is located outside of said stream surrounding said collector.

14. An amplifying space discharge device which comprises an evacuated elongated cylindrical non-conducting envelope, a first thermionic cathode and a first collector electrode at opposite ends of said envelope defining a path of travel for electrons, at least one electron accelerating electrode spaced apart from said first cathode between said first cathode and said collector, means coupled to said first cathode to direct a stream of electrons from said first cathode to said first collector, an elongated second thermionic cathode extending lengthwise along said path within said envelope for a distance of at least several signal wavelengths in said stream between said accelerating electrode and said first collector, a second collector electrode situated substantially coaxially with said second cathode within said envelope and extending over substantially the same portion of said path, means coupled to said second cathode to direct electrons radially of said stream in substantially all directions perpendicular to the axis thereof from said second cathode to said second collector, means coupled to said stream between said accelerating electrode and said second cathode to supply signal wave energy thereto, and means coupled to said stream between said second cathode and said first collector to withdraw amplified signal wave energy therefrom.

15. An amplifying space discharge device in accordance

with claim 14 in which said second cathode is located centrally within said stream and said second collector is tubular and is located outside of said stream surrounding said second cathode.

16. An amplifying space discharge device in accordance with claim 14 in which said second collector is located centrally within said stream and said second cathode is located outside of said stream surrounding said second collector.

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