Aug. 16, 1955 S. E. WEBBER 2,715,697

MICROWAVE ELECTRON DISCHARGE DEVICE

Filed Feb. 27, 1951 2 Sheets-Sheet 1

Fig. 1.

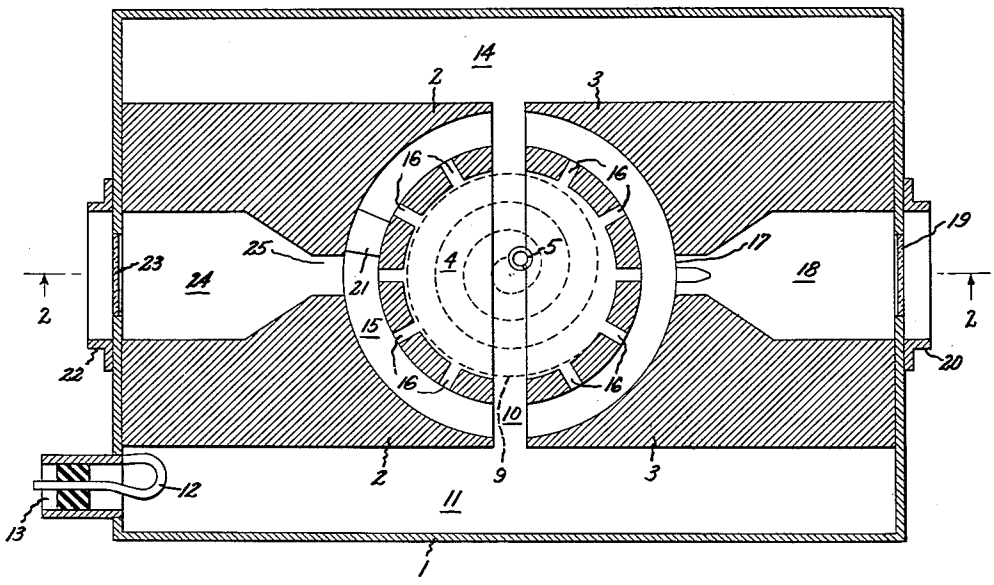
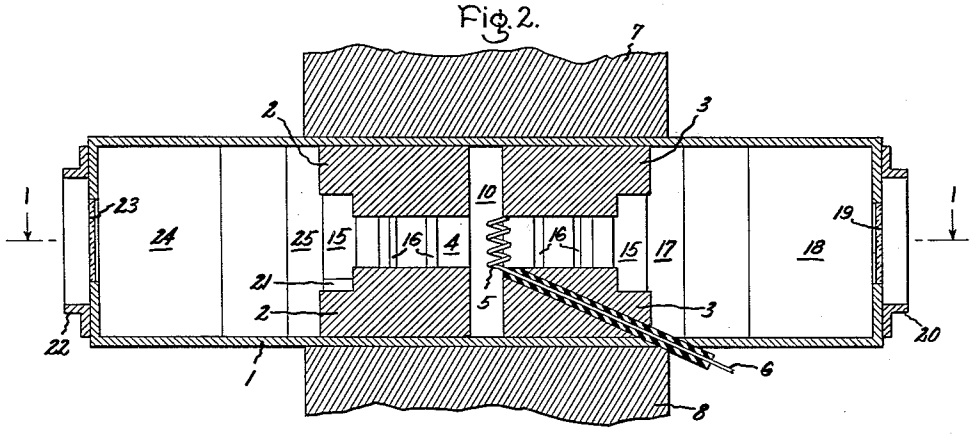


Fig. 2.



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Fig. 3.

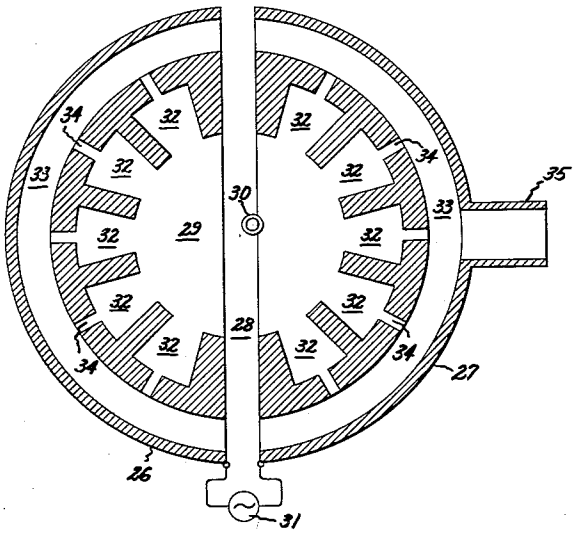


Fig. 4.

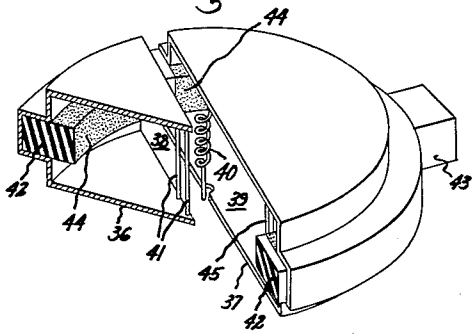
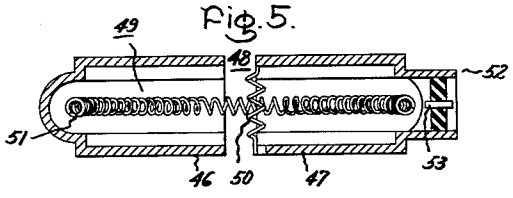


Fig. 5.



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2,715,697

MICROWAVE ELECTRON DISCHARGE DEVICE

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Application February 27, 1951, Serial No. 212,939

19 Claims. (Cl. 315—39)

This invention relates to improvements in microwave apparatus, and has for an object the provision of improved apparatus for generating or amplifying electromagnetic waves having a frequency in the order of three hundred thousand megacycles. Other objects and advantages will appear as the description proceeds.

It is known that under certain conditions an electromagnetic wave transmitted in proximity to a high velocity electron beam can absorb energy from the beam. In previous devices utilizing this principle for the generation or amplification of microwaves, an important limitation has been that electrons must be accelerated to high velocities, requiring high accelerating voltages. In the present invention, this difficulty is avoided by using the cyclotron principle, by which electrons are accelerated to very high velocities by repeated passage across accelerating gaps driven by a relatively small alternating voltage. In this way, electrons may be accelerated relatively easily up to exceedingly high velocities in the order of one-half the velocity of light. These high velocity electrons transfer energy to an electromagnetic wave transmitted at nearly the same velocity through a wave guide structure arranged about the periphery of the electron orbits.

It has previously been proposed that electrons accelerated through the cyclotron principle may be used to generate electromagnetic waves by their action upon resonant, oscillatory structures. In the present invention, such oscillatory structures are not essential, since the beam interacts with a continuously moving wave transmitted at a velocity near that of the electrons.

The features of this invention which are believed to be novel and patentable are pointed out in the claims which form a part of this specification. For a better understanding of the invention, reference is made in the following description to the accompanying drawings, in which Fig. 1 is a horizontal section of improved microwave apparatus, Fig. 2 is a vertical section of the same apparatus, Fig. 3 is a schematic horizontal section of a modification, Fig. 4 is a schematic perspective view, partly in section, of other improved microwave apparatus, and Fig. 5 is a schematic vertical section of other improved microwave apparatus.

Referring now to Figs. 1 and 2, an evacuated structure comprises an envelope or case 1 and a pair of hollow electrodes 2 and 3. Each of the electrodes 2 and 3 contains a substantially semi-circular hollow portion, so that together they form a substantially circular hollow space 4, as shown. Within this circular hollow space is an electron-emitting cathode 5, which may be a small metal filament connected at one end to a lead 6 and connected at its other end to case 1 through electrode 3. Voltage applied between case 1 and lead 6 in the conventional manner causes current to flow through filament 5, which heats the filament sufficiently for thermionic emission of electrons. Means such as a magnet having pole pieces 7 and 8 produces a magnetic field through space 4 which causes electrons emitted by cathode 5 to travel in orbital paths about the cathode, as represented by dotted lines 9.

Electrodes 2 and 3 are separated by an accelerating gap 10, across which an accelerating voltage is provided as hereinafter explained. The electrons traveling in orbital paths about the cathode repeatedly traverse gap 10, and at each crossing are accelerated so that the electrons gain velocity and travel in orbits of increasing radius until they strike electrode 2 or electrode 3. Electrons in the outer orbits travel at exceedingly high velocities, which may be in the order of one-half the velocity of light.

It is know that electrons traveling in orbital paths of the type described, having linear velocities below that at which the relativistic increase in mass becomes significant, travel at a constant angular velocity determined solely by the strength of the magnetic field, regardless of the linear velocity of the electrons. The relativistic increase in mass at very high linear velocities limits the maximum electron velocities obtainable with this arrangement to about one-half the velocity of light. Accordingly, the electrons may be accelerated up to a velocity of about one-half the velocity of light by an alternating voltage applied across the accelerating gap 10 in synchronism with the period of angular rotation of the electrons. Preferably, this alternating voltage is supplied by electromagnetic waves within a resonant cavity 11 to which the electromagnetic energy is supplied, through a probe 12 and a coaxial connection 13, from any suitable source. A similar resonant cavity 14 may be provided at the other end of the gap 10, as shown, for better excitation of the gap. Cavity 14 is excited by the voltage across the gap, and hence requires no external excitation.

An annular wave guide 15 extends around the outside of circular space 4, and hence about the periphery of the electron orbits. As is known, the phase or wave velocity of electromagnetic waves transmitted by a wave guide is greater than the velocity of light, especially at frequencies near the cut-off frequency of the wave guide. However, since the radius of the wave guide is greater than the radii of the electron orbits, the electromagnetic waves transmitted by the wave guide may have nearly the same angular velocity as the electrons, although they have much larger linear velocities. The proportions of wave guide 15 are such that the angular velocity of electromagnetic waves transmitted, of the frequency which is desired to generate or amplify, is near and slightly less than the angular velocity of electrons in the outermost orbit. Interaction between the waves transmitted by wave guide 15 and the electrons in the outermost orbits occurs through a plurality of slots 16, or other suitable coupling means, in the inner wall of the wave guide. In this inter-action, energy is transferred from the electrons to the electromagnetic waves, so that the waves are amplified and increase in amplitude. In this way, electromagnetic waves of substantial amplitude are quickly built up within wave guide 15. These amplified waves are necessarily of the desired frequency, since waves of other frequencies are transmitted by the wave guide at different velocities, and only those waves traveling at angular velocities near the velocity of the electrons inter-act with the electrons and receive energy therefrom. Slots 16 also serve the purpose of reducing somewhat the velocity of waves in the wave-guide, and thus assist in matching the wave velocity to the electron velocities.

Since any random disturbance may initiate an electromagnetic wave which will be amplified and quickly built up to a substantial amplitude, the device described is inherently an oscillator at a frequency determined by the wave guide dimensions and the velocity of the fully accelerated electrons in the outermost electron orbits. This frequency can be adjusted, within limits, by adjusting the electron velocities, by simultaneously adjusting the

strength of the magnetic field and the frequency of the driving voltage across gap **10**. To utilize these oscillations, a portion of the electromagnetic wave within wave guide **15** may be transmitted through a slot **17**, or other suitable coupling means, in the outer wall of a wave guide to a resonant chamber **18**, and thence through a conventional resonant window **19** in the wall of envelope **1** to an output connection **20**. The output will be highest when the output frequency is an integral multiple of the input frequency.

The device may be used as an amplifier if the inherent tendency of the apparatus to oscillate is suppressed. This may be done by placing an attenuator **21** at a suitable location within wave guide **15**. Attenuator **21** may be a small pad of lossy material which absorbs enough energy from electromagnetic waves within the wave guide to prevent random disturbances from building up to substantial amplitude. Input signals may then be fed into the wave guide through an input connection **22**, a resonant window **23**, a resonant chamber **24** and a slot **25**. When input signals are fed into the wave guide **15**, these signals travel around the wave guide and are amplified by inter-action with the electrons in circular space **4**, thereby producing oscillations of larger amplitude at output connection **20**. In the absence of an input signal, attenuator **21** absorbs sufficient energy to prevent substantial oscillations in wave guide **15**, and thereby reduces the output signal to a negligible value.

Fig. 3 shows a modification especially useful as an oscillator. In this figure, two hollow electrodes **26** and **27**, separated by an accelerating gap **28**, form a substantially circular space **29**. Within space **29** is a source of electrons, such as electron-emitting cathode **30**. Accelerating voltage is provided across gap **28** by any suitable means **31**. A suitable envelope or case, not shown, is provided to keep space **29** evacuated, and a magnetic field is provided through space **29** by suitable means, not shown, such as a magnet. The electrons travel in orbital paths about cathode **30**, and are accelerated to high velocities by repeatedly traversing gap **28**.

A plurality of small resonant cavities **32** are arranged around the periphery of the electron orbits, as shown. These cavities are connected to an annular wave guide **33** through a plurality of slots **34**, or other suitable means. An output connection from the wave guide is provided at **35**.

In the operation of this modification, the accelerated electrons supply energy to maintain electromagnetic oscillations in each of the small resonant cavities **32**. These oscillations supply energy through slots **34** to maintain a traveling electromagnetic wave in wave guide **33**. The radius of wave guide **33** is approximately twice the radius of the outermost electron orbits, so that waves traveling in the wave guide at greater than the speed of light have an angular velocity nearly equal to that of electrons in the outermost electron orbit traveling at a linear velocity of one-half the speed of light. Since the angular velocities are nearly equal, the proper relationship exists for the transfer of energy from the electrons to the traveling wave in the wave guide.

Fig. 4 shows an improved microwave apparatus useful for generating or amplifying waves of very short wave length. In this figure, two hollow electrodes **36** and **37** separated by an accelerating gap **38** form a substantially circular space **39**. Within space **39** is a source of electrons, such as electron-emitting cathode **40**. A suitable case or envelope, not shown, is provided to keep space **39** evacuated, and a magnetic field is provided through space **39** by suitable means, not shown, such as a magnet. The electrons travel in orbital paths about the cathode, and are accelerated to high velocities, to one-half the velocity of light, for example, by repeatedly traversing gap **38**, across which an alternating accelerating voltage is provided by any suitable means, not shown. Wires **41** may be connected to electrode **36**, as shown, to aid the initial acceleration of electrons across the gap.

Around the periphery of the electron orbits is a wave guide structure comprising a ring **42** of dielectric material. Since this ring of dielectric material is a good electrical insulator, it may extend continuously across gap **38** without short-circuiting the accelerating voltage. It is known that a dielectric wave guide of this type can transmit electromagnetic waves of certain frequencies at velocities substantially below the velocity of light. At a particular frequency, determined by the dielectric constant and dimensions of ring **42**, the transmitted waves have a velocity nearly the same as that of fully accelerated electrons in the outermost electron orbits, which may be about one-half the velocity of light. A portion of the electromagnetic field of the waves transmitted by wave guide **42** extend through the inner surface of the dielectric ring into the electron orbit space, and thus inter-acts with the accelerated electrons so that the electrons transfer energy to the electromagnetic wave and amplify any random disturbance to a wave of substantial amplitude traveling around the annular wave guide. A portion of this amplified wave may be utilized through an output connection **43** coupled to the wave guide in any suitable manner, for example, by an additional piece of dielectric material attached to ring **42**.

Since the apparatus has an inherent tendency to oscillate at a frequency determined by the electron velocities and the characteristics of the wave guide, it is especially useful as a generator of electromagnetic waves having very short wave lengths. For use as an amplifier, an input connection is provided at the other side of the annular wave guide, similar to output connection **43**, and an attenuator pad of lossy material is attached to the wave guide at a suitable location to absorb sufficient energy from the electromagnetic wave to suppress the inherent tendency of the apparatus to oscillate.

To prevent the accumulation of undesired charges from electrons striking the inner surface of ring **42**, a very thin layer **44** of electrically conducting material is coated on the inner surface of the dielectric ring, as shown. The thickness and conductivity of film **44** are just sufficient to prevent the accumulation of charges on the inside of the dielectric ring, and are not sufficient to prevent the penetration of electromagnetic waves from the wave guide into the region of the electron orbits. If desired, a collector electrode **45**, which may be a small strip of metal positioned just inside of ring **42**, may be provided to remove electrons from the outermost orbit before they strike the dielectric ring. It may be noted that this form of the apparatus has a very simple, sturdy and economical structure.

Refer now to Fig. 5, which illustrates another improved microwave apparatus. Two hollow electrodes **46** and **47**, separated by an accelerating gap **48**, form a substantially circular space **49**. Within this space there is an electron-emitting cathode **50**. A suitable case or envelope, not shown, is provided to keep space **49** evacuated, and a magnetic field is provided through space **49** by suitable means, not shown, such as a magnet. The electrons travel in orbital paths about cathode **50**, and are accelerated to high velocities by repeatedly traversing gap **48**, across which an accelerating voltage is provided by suitable means, not shown.

Around the periphery of the electron orbits is a wave guide structure comprising an annular helix **51**. Helix **51** is proportioned to transmit electromagnetic waves at a velocity near that of the fully accelerated electrons in the outermost electron orbits. This wave acquires energy from the electrons in the manner hereinbefore described, and thereby is amplified. A portion of this amplified wave may be supplied to an output connection **52** through a probe **53**. For use as an amplifier, an input connection (not shown) is provided at the other side of the helix, and a suitable attenuator is coupled

to the helix to suppress the inherent tendency of the apparatus to oscillate.

Having described the principle of this invention in the best modes in which I have contemplated employing that principle, I wish it to be understood that the examples described are illustrative only, and that other means may be employed without departing from the true scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Microwave apparatus comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to high velocities, and a wave guide structure around the periphery of said orbital paths for transmitting electromagnetic waves at substantially the same angular velocity as the fully accelerated electrons.

2. Microwave apparatus comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to substantially one-half the velocity of light, and a wave guide structure around the periphery of said orbital paths for transmitting electromagnetic waves at substantially the same angular velocity as the fully accelerated electrons.

3. A microwave oscillator comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to high velocities, a wave guide structure around the periphery of said orbital paths for transmitting electromagnetic waves at substantially the same angular velocity as the fully accelerated electrons, whereby such waves gain energy from the electrons and any random disturbance is quickly built up to electromagnetic waves of substantial amplitude, and an output connection coupled to said wave guide for utilizing a portion of said amplified waves.

4. A microwave amplifier comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to high velocities, a wave guide structure around the periphery of said orbital paths for transmitting electromagnetic waves at substantially the same angular velocity as the fully accelerated electrons, an input connection coupled to said wave guide for supplying electromagnetic waves to the wave guide, which waves travel around the wave guide and receive energy through inter-action with the accelerated electrons, whereby the electromagnetic waves are amplified, and an output connection coupled to said wave guide for utilizing a portion of the amplified waves.

5. A microwave amplifier comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to high velocities, a wave guide structure around the periphery of said orbital paths for transmitting electromagnetic waves at substantially the same angular velocity as the fully accelerated electrons, an input connection coupled to said wave guide for transmitting thereto electromagnetic waves which travel around the wave guide and absorb energy by inter-acting with the accelerated electrons, whereby the electromagnetic waves are amplified, an output connection coupled to said wave guide for utilizing a portion of said amplified waves, and an attenuator coupled to said wave guide for suppressing the inherent tendency of the apparatus to oscillate.

6. A microwave amplifier comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to substantially one-half the velocity of light, a wave guide structure around the periphery of said orbital paths for transmitting electromagnetic waves at substantially the same angular velocity on the fully accelerated electrons, whereby said waves gain energy through inter-action with the accelerated electrons and any random disturbance is amplified to an electromagnetic wave of substantial amplitude, and an output connection coupled to said wave guide for utilizing a portion of such amplified waves.

7. A microwave amplifier comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to substantially one-half the velocity of light, a wave guide structure around the periphery of said orbital paths for transmitting electromagnetic waves at substantially the same angular velocity as the fully-accelerated electrons, an input connection coupled to said wave guide for transmitting thereto electromagnetic waves which travel around the wave guide and are amplified by inter-action with the accelerated electrons, and an output connection coupled to said wave guide for utilizing a portion of such amplified waves.

8. A microwave amplifier comprising an evacuated structure including a plurality of hollow electrodes forming a substantialy circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to substantially one-half the velocity of light, a wave guide structure around the periphery of said orbital paths for transmitting electromagnetic waves at substantially the same angular velocity as the fully-accel-

erated electrons, an input connection coupled to said wave guide for transmitting thereto electromagnetic waves which travel about the wave guide and are amplified by inter-action with the accelerated electrons, an output connection coupled to said wave guide for utilizing a portion of such amplified waves, and an attenuator coupled to said wave guide for suppressing the inherent tendency of the apparatus to oscillate.

9. Microwave apparatus comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to high velocities, an annular hollow wave guide having an inner wall immediately surrounding said circular space, said inner wall having a plurality of slots connecting said wave guide to said circular space, an output connection, and means coupling said output connection to said wave guide.

10. A microwave oscillator comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, a plurality of resonant chambers connected to each end of said gap, means to supply electromagnetic energy to at least one of said resonant chambers, whereby an alternating voltage is applied across said gap which accelerates said electrons to high velocities, an annular hollow wave guide having an inner wall immediately surrounding said circular space, a plurality of slots in said inner wall connecting said wave guide to said circular space, an output connection, and means coupling said output connection to said wave guide.

11. A microwave amplifier comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, a plurality of resonant chambers connected to respective ends of said gap, means to supply electromagnetic energy to at least one of said resonant chambers whereby an alternating voltage is provided across said gap which accelerates said electrons to high velocities, an annular hollow wave guide having an inner wall immediately surrounding said circular space, a plurality of slots in said inner wall connecting said wave guide to said circular space, input and output connections, means coupling said input and output connections to said wave guide, and an attenuator of lossy material within said wave guide to suppress the inherent tendency of said apparatus to oscillate.

12. A microwave amplifier comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to high velocities, a plurality of resonant cavities arranged around the periphery of said circular space and connected thereto, a hollow annular wave guide having an inner wall immediately surrounding said cavities, said inner wall having a plurality of slots connecting said wave guide and said cavities, said annular wave guide having a radius substantially twice as large as the radius of said circular space, an output connection, and means coupling said output connection to said wave guide.

13. Microwave apparatus comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to high velocities, and a wave guide structure comprising a closed ring of dielectric material immediately surrounding said circular space.

14. A microwave oscillator comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to high velocities, a wave guide structure comprising a circular ring of dielectric material immediately surrounding said circular space, and an output connection coupled to said wave guide.

15. A microwave amplifier comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to high velocities, a wave guide structure comprising a circular ring of dielectric material immediately surrounding said circular space, input and output connections coupled to said wave guide structure, and an attenuator coupled to said wave guide structure to suppress the inherent tendency of the apparatus to oscillate.

16. A microwave amplifier comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to high velocities, a wave guide structure comprising a circular ring of dielectric material immediately surrounding said circular space, input and output connections coupled to said wave guide structure, and a thin film of electrically conductive material coated upon the inner surface of said annular ring.

17. Microwave apparatus comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to high velocities, and a wave guide structure comprising an annular helix immediately surrounding said circular space.

18. A microwave oscillator comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a

magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply alternating voltage across said gap whereby said electrons are accelerated to high velocities, a wave guide structure comprising an annular helix immediately surrounding said circular space, and an output connection coupled to said wave guide structure.

19. A microwave amplifier comprising an evacuated structure including a plurality of hollow electrodes forming a substantially circular evacuated space, said hollow electrodes being separated by a gap, an electron-emitting cathode within said circular space, means to provide a magnetic field through said space whereby the electrons emitted by said cathode travel in orbital paths about the cathode and repeatedly traverse said gap, means to apply

alternating voltage across said gap whereby said electrons are accelerated to high velocities, a wave guide structure comprising an annular helix immediately surrounding said circular space, and input and output connections respectively coupled to said wave guide structure.

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