Feb. 25, 1947. A. E. BOWEN 2,416,283

ULTRA-HIGH FREQUENCY ELECTRONIC DEVICE

Filed July 3, 1942

FIG. 1

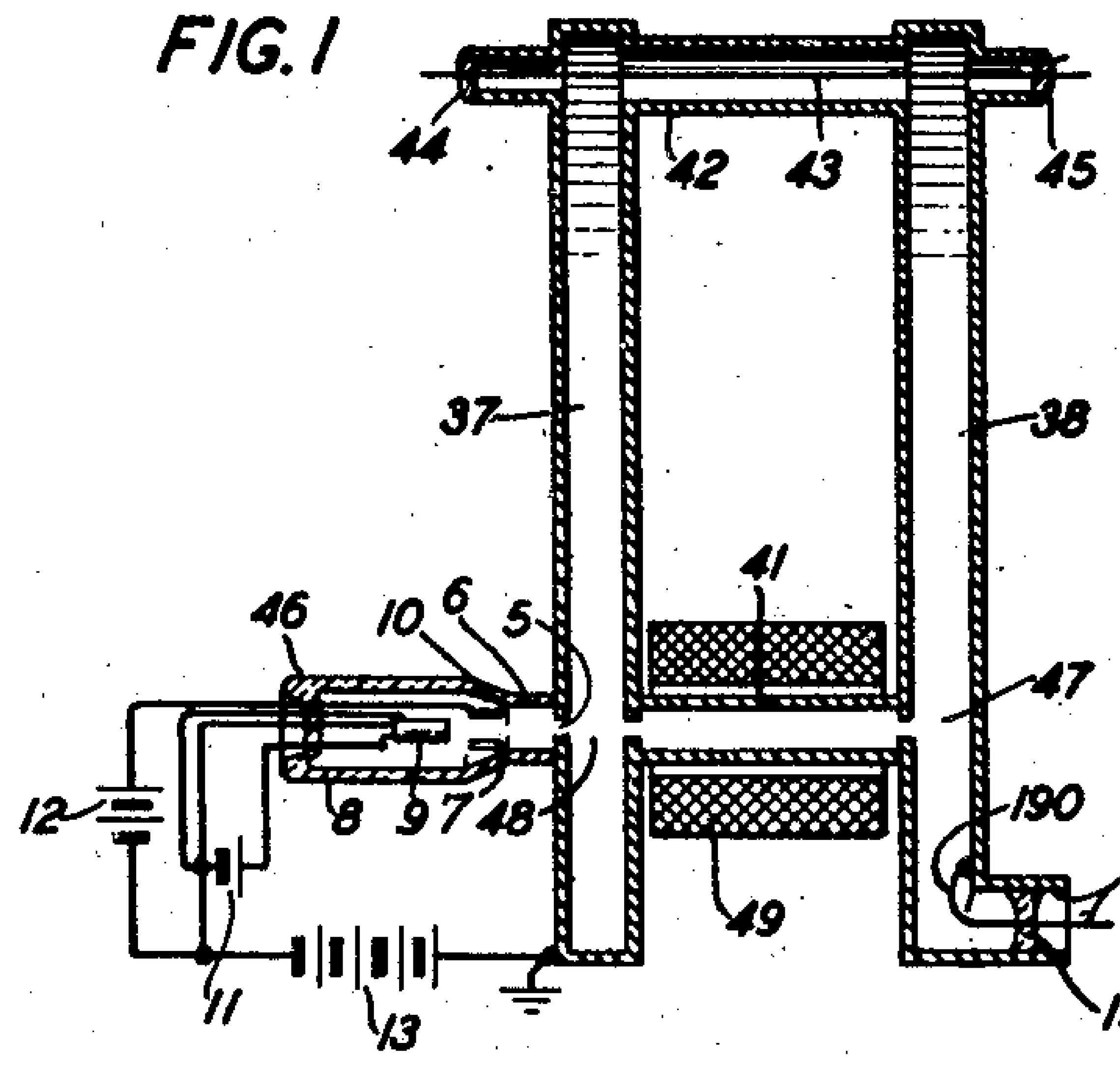


FIG. 2

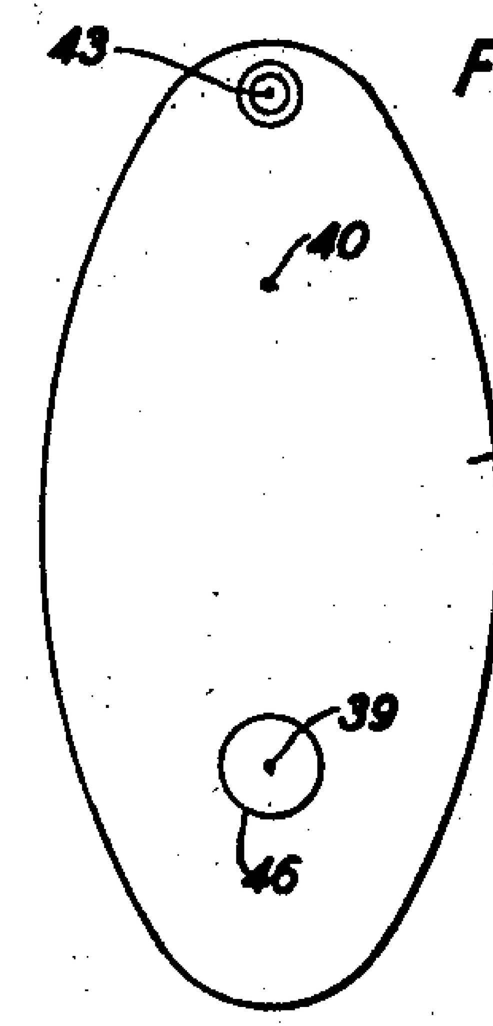


FIG. 3

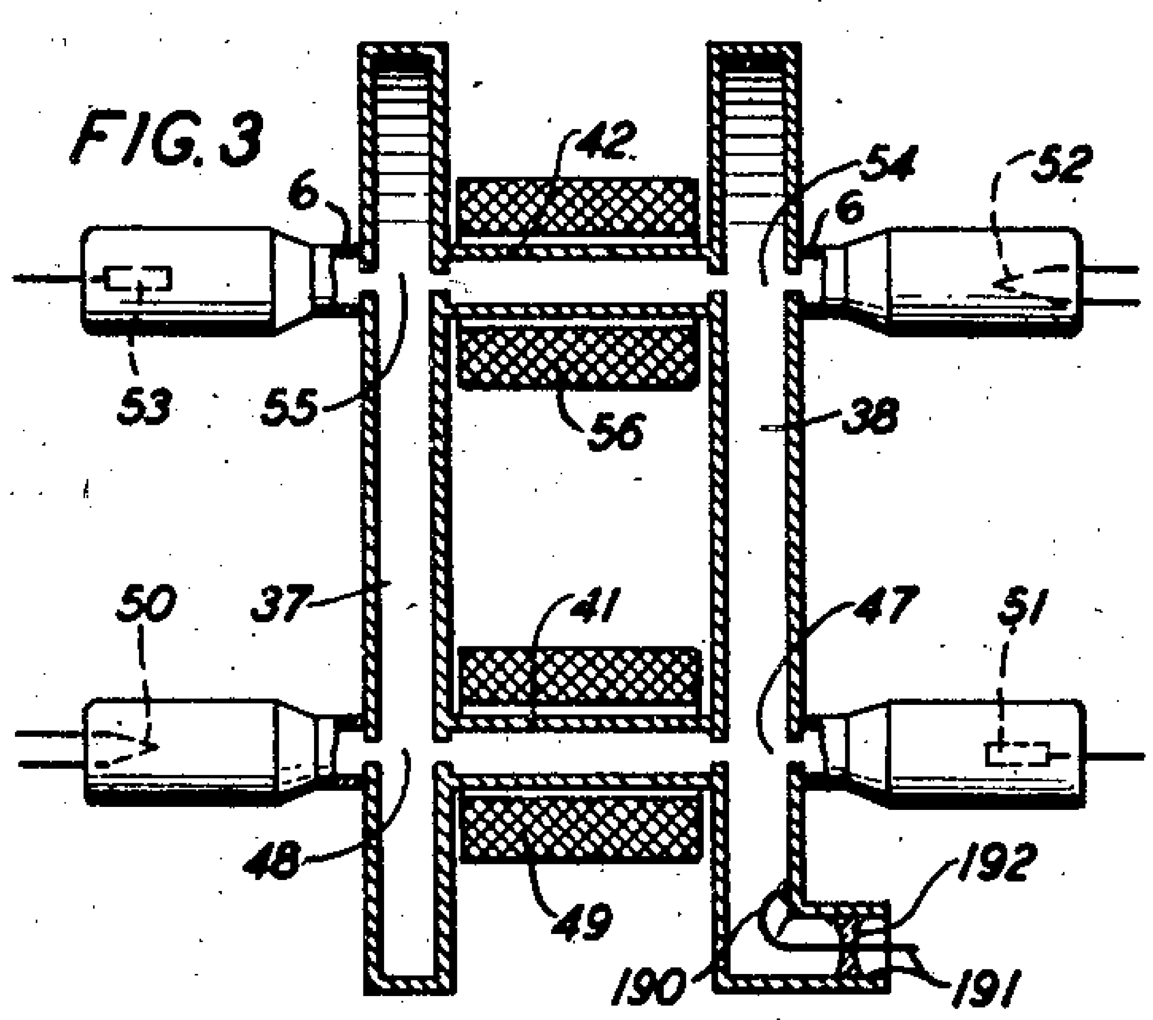


FIG. 4

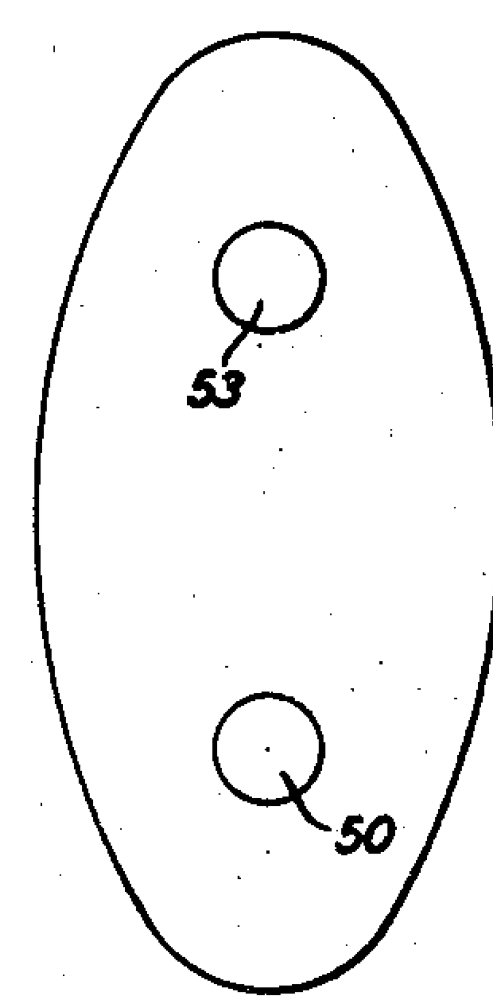


FIG. 5

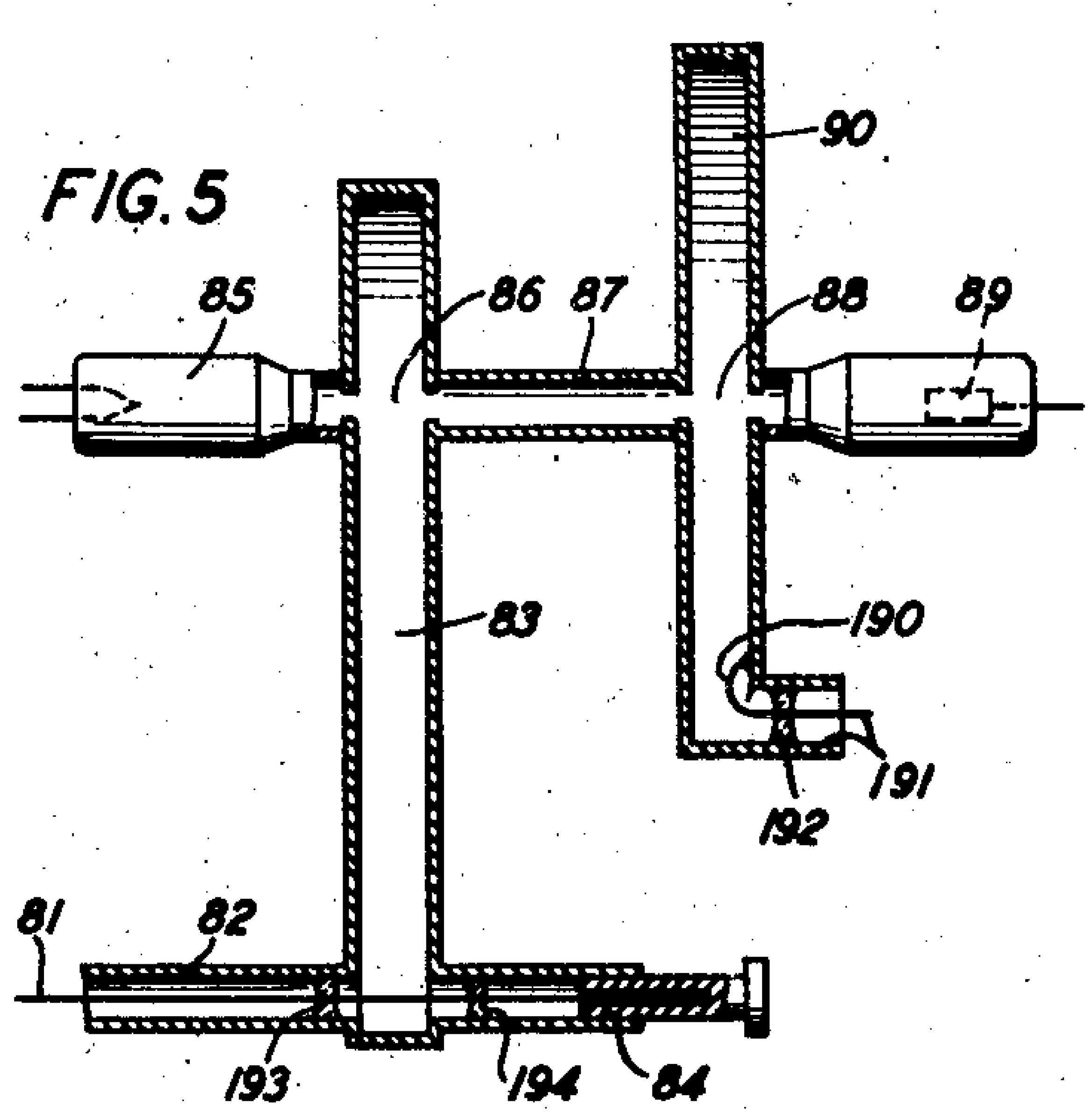
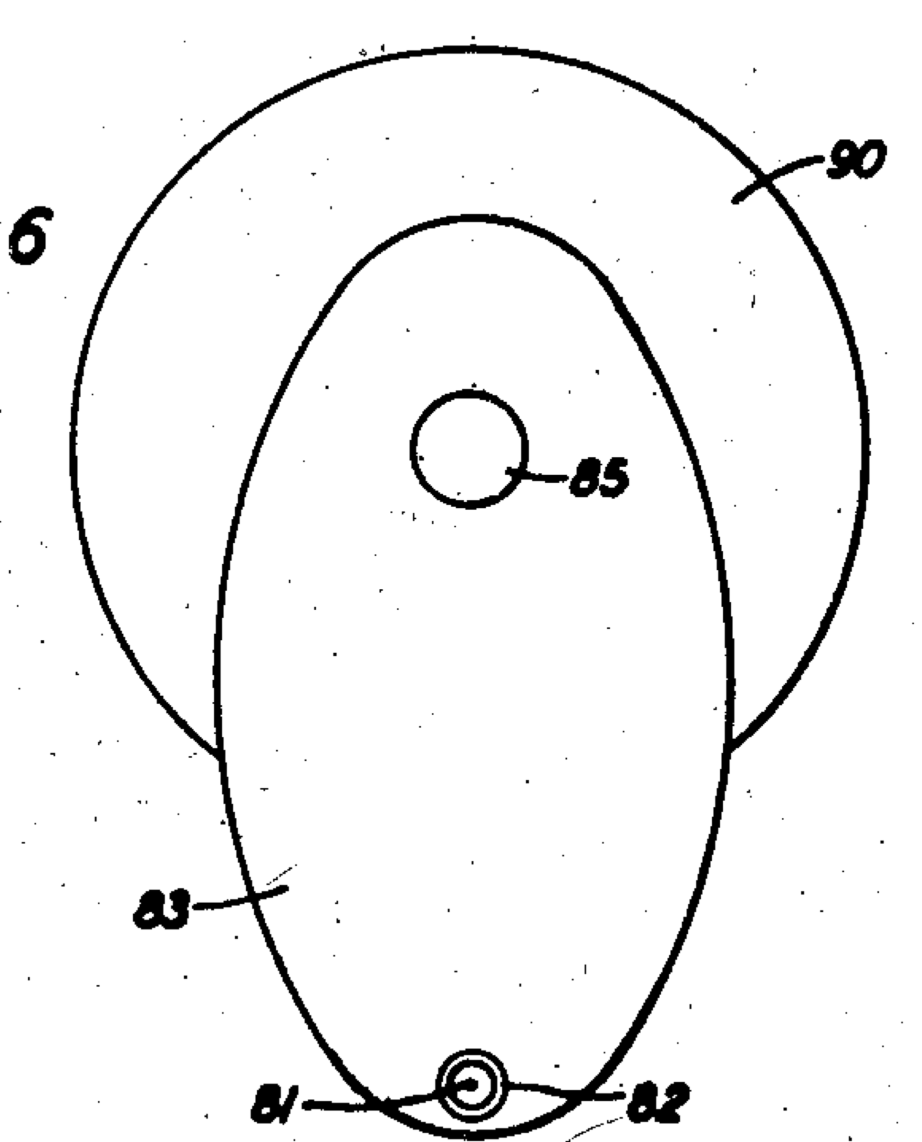


FIG. 6



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ULTRA HIGH FREQUENCY ELECTRONIC DEVICE

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Application July 3, 1942, Serial No. 449,581

5 Claims. (Cl. 315—6)

1

This invention relates to systems employing resonators and resonant cavities so shaped and constructed as to be suitable for reaction with an electron stream to enable an electromagnetic field which may be set up in the resonator or resonant cavity to induce a variation in some characteristic property of the electron stream, or, to permit an interchange of energy between the resonator and the electron stream.

In particular the resonator may be in the shape of a short section of an elliptical cylinder, hollow inside and closed off by parallel plane sheets. A wave guide may be connected to the resonator at a focal point or elsewhere according to the amount of impedance to be provided at the junction point.

The invention is applicable generally to amplifiers, oscillators, modulators, detectors and the like particularly at ultra-high frequencies, wherever it is desired to effect direct interaction between an electromagnetic field and an electron stream.

This application is a continuation-in-part of my copending application Serial No. 387,432, filed April 8, 1941, Patent 2,408,409, granted October 1, 1946.

The combination of two elliptical cavity resonators with electronic coupling between one pair of respective focal points in the resonators and with a two-directional coupling means connected between another pair of corresponding points in the two resonators, not necessarily focal points, disclosed herein, is claimed in my copending application Serial No. 621,365 filed October 9, 1945, assigned to the same assignee as the present application.

An oscillator and harmonic generator formed by an elliptical cavity resonator and a circular cavity resonator with electronic coupling between a focal point of the elliptical resonator at the center of the circular resonator, disclosed herein, is claimed in my copending application Serial No. 621,366 filed October 9, 1945, and assigned to the same assignee as the present application.

The invention is described with reference to a number of illustrative examples, while its scope is indicated by the appended claims.

In the drawing:

Figs. 1 and 2 show a sectional view and a plan or elevational view, respectively, of an oscillator employing elliptical resonators and a stream of electrons;

Figs. 3 and 4 show similar views of another embodiment, employing elliptical resonators and a pair of electron streams, one stream through each of the foci of the ellipse; and

2

Figs. 5 and 6 show similar views of an amplifier or a frequency multiplying arrangement employing an elliptical resonator and a circular resonator.

In Figs. 1 and 2 there are shown two substantially elliptical resonators **37** and **38** with focal points indicated at **39** and **40**. The resonators may be built with walls of copper or other suitable material, the inner surfaces, at least, being preferably highly conductive. Each resonator may be viewed as comprising a short section of elliptical cylinder closed off by parallel, plane end walls. Apertures are cut through the plane walls of each ellipse at focus **39** and the resonators are joined by a cylindrical conductive tube **41** covering the apertures. Additional apertures are cut through the resonator walls preferably near the periphery at a point remote from focus **39** and the resonators are joined at this point by a cylindrical conductive tube **42**. Coaxially with tube **42** is placed a rod of conductive material **43** which is held in place by insulating hermetic seals at **44** and **45**. A hollow conductive cylinder **6** is fastened over an aperture **5** in the left-hand end wall of the resonator **37** as viewed in Fig. 1. The tube **6** is joined by means of a suitable hermetic seal **7** to an insulating envelope **8** of glass or other suitable material. Within the envelope **8** are provided the usual elements of an electron gun or beam projector **46** of any suitable type comprising, for example, a cathode **9**, and an accelerating electrode **10** cooperating with the cylinder **6** to direct an electron beam through the apertures in the resonators **37** and **38** aligned with the axis of tube **41**. A pair of gaps **47** and **48** are constituted, as indicated, in the path of the beam. The gap **48** is defined by the edges of the aperture **5** and the edges of an aperture in the right-hand end wall of the resonator **37** at the entrance to the tube **41**. The gap **47** is defined by the edges of an aperture in the left-hand end wall of the resonator **38** and the right-hand end wall of that resonator. Batteries **11**, **12** and **13** or other suitable sources may be provided, respectively, for heating the cathode **9**, energizing the accelerating electrode **10** and applying an accelerating potential to the conductive system comprising the resonators **37** and **38**, and the tubes **41**, **42** and **6**. The tube **41** serves not only as a passage for the electron stream but also as an electromagnetic shield defining a drift space within which the electron bunching action hereinafter described may be effectuated free from fluctuating electromagnetic fields.

In the operation of the arrangement of Figs. 1 and 2, the electrons comprising the electron stream from the gun 46 are subjected at the gap 48 to interaction with any electromagnetic field which may exist in the resonator 37 and at the gap 47 with any such field that may exist in the resonator 38. An accidental irregularity in the charge density of the electron stream will suffice to set up an electromagnetic wave in the resonator 38 as the irregularity passes across the gap 47. The wave thus set up spreads through the cavity of the resonator 38 and converges again at the focus 40, inducing current in the conductor 43 where the latter crosses the cavity. An induced wave travels over the coaxial transmission line comprising the tube 42 and the conductor 43 into the resonator 37. A wave is induced in the latter resonator which wave in the course of propagation converges upon the gap 48. Each electron in its passage across the gap 48 either takes energy from or gives energy to the electromagnetic field in the resonator 37, depending upon the phase of the field during its transit of the gap. The velocities of the electrons are varied in accordance with this energy interchange.

After leaving the gap 48, the velocity-varied electrons pass through the tube 41 where a grouping or bunching effect takes place, those electrons which have lost energy and have, as a consequence, been slowed down being overtaken by other electrons which entering later, have gained energy and have speeded up. Consequently, at a point some distance to the right of the gap 48, the electrons are traveling in more or less well-defined groups. Upon reaching the gap 47 the bunches of electrons may, if the length of the tube 41 and the initial speed of the electrons have been adjusted correctly, cross the gap 47 in opposition to the high frequency electromagnetic field, thus contributing energy to the field, and in greater amounts than are absorbed by the thinly distributed electrons which may cross the gap 47 during the unfavorable phase of the high frequency field. The net energy contributed by the electron stream to the field tends to sustain and build up the original wave and thus to maintain the system in oscillation.

It may be further noted that the wave above described, upon first arriving at the gap 48 and there initiating an electron group in the electron stream, is, in effect, reflected back through the resonator 37 and coaxial line 42, 43 into the resonator 38 and to gap 47. If the velocity of the electrons in the beam is adjusted so that the electron bunch reaches the gap 47 at the same time the reflected wave arrives there, or an integral number of cycles later, a fresh supply of energy is given to the wave and the oscillation is maintained. The adjustment in this case will also satisfy the condition for oscillation specified in the preceding paragraph.

The type of construction shown in Figs. 1 and 2 accommodates a magnetizing coil 49 which may be wound around the cylinder 41 and used to improve the collimation and focusing of the electron stream. Energy may be extracted from the system by any suitable means, such as a coupling loop 190 connected across a coaxial transmission line 191. The vacuum chamber will include the envelope 8, the resonators 37, 38 and the tubes 6, 41, 42 and the closure may be completed with an insulating seal 192. The spent electrons are collected at the right-hand end wall of the resonator 38 and returned to the battery 13.

Figs. 3 and 4 show an arrangement similar to that shown in Figs. 1 and 2 except that two electron streams are employed, one in each of the tubes 41, 42. In order to secure the proper phase relations for the waves, the electron streams are oppositely directed. The resonators 37 and 38 are shown as in Fig. 1. An electron gun represented schematically by a cathode 50 is arranged to direct a stream of electrons across the gap 48, down the interior of the tube 41 and across the gap 47 to a collector plate 51. A second electron gun represented by a cathode 52 is located at the focal point 40 and arranged to direct an electron beam across a velocity-varying gap 54, through the interior of the tube 42 and across an energy extracting gap 55 to a collector 53. The axial rod 43 and the seals 44 and 45 are not used in this embodiment. A second magnetizing coil 56 may be placed around the outside of the tube 42.

In the operation of the system shown in Figs. 3 and 4, an electromagnetic disturbance occurring in the gap 47 serves to set up a wave which is focused upon the gap 54 and there effects a velocity variation of the electron stream from the cathode 52. The velocity-varied stream from the cathode 52 in crossing the gap 55 a brief time later sets up a wave which is focused upon the modulating gap 48 and produces a velocity variation of the electron stream from the cathode 50. This velocity-varied stream a short time later arrives at the gap 47 and sets up a new disturbance. If the transit times of the two electron streams through the tubes 41 and 42, respectively, are properly adjusted, the waves originating at the gaps 47 and 55, respectively, will be in proper phase to maintain the oscillations. Viewed as a feedback means, either electron stream constitutes an electronic feedback as distinguished from the coaxial line feedback of the system of Figs. 1 and 2.

The construction shown in Figs. 1 and 3 will be observed to require a minimum of insulating material and practically none in the space containing the high frequency field.

Figs. 5 and 6 show an application of the invention to an amplifier or a frequency multiplier and also combine the use of elliptical and circular resonators. An input coaxial line with inner conductor 81 and outer conductor 82 intersects an elliptical resonator 83. The right-hand portion of the coaxial line beyond the resonator 83 is adjustable for tuning purposes by means of a piston 84 slidable over the conductor 81. An electron gun represented schematically at 85 is arranged to send an electron stream across a gap 86 in the resonator 83, through a drift tube 87 and across a gap 88 to a collector 89. The gap 88 is situated at the center of a circular resonator 90. The plan view is shown in Fig. 6.

In the operation of the system of Figs. 5 and 6 a wave to be amplified or to have its frequency multiplied is brought into the system through the coaxial line 81, 82. The incoming wave sets up waves in the elliptical resonator 83 which waves are focused upon the gap 86 where velocity variation of the electron stream from the electron gun 85 is effected. After passing through the drift tube 87, the electron stream with its electrons bunched supplies energy at the gap 88 to set up an electromagnetic field in the circular resonator 90. The waves generated in the resonator 90 may be of greater energy and hence amplified with respect to the waves supplied to the input of the device. Theoretical considerations show that the electron stream crossing the output gap is characterized by a rather complex variation in space charge density which renders the stream capable of exciting oscillations of multiplied frequency in a properly designed resonator. To take advantage of frequency multiplication, the resonator 80 may be designed with sufficiently small dimensions to resonate a desired harmonic of the input wave. If amplification alone is desired the resonator is preferably designed to resonate at the frequency of the wave impressed upon the system by the coaxial line 81, 82.

The impedance presented to the line 81, 82 by the resonator 83 is dependent upon the point of connection of the line to the resonator. By proper selection of this point an impedance match may usually be secured. The point may be found by calculation or trial and will not, in general, be at the focus of the ellipse.

What is claimed is:

1. An oscillator comprising two spaced-hollow elliptical resonators, means adjacent focal points of said resonators to project an electron stream successively through one of said resonators at a focal point thereof and into the other resonator at a focal point thereof, a shield surrounding the portion of the path of said electron stream between said resonators for shielding said electron stream from fluctuating electromagnetic fields in the space between said resonators, and feedback coupling means extending between the interiors of said resonators at another pair of respective focal points.

2. An electronic oscillator comprising a pair of elliptical resonators and means connecting corresponding focal points of each resonator together and including means for producing a pair of electron streams, each of the respective streams when in operation forming a substantially unidirectional coupling between a focal point in one of said resonators and a focal point in the second of said resonators.

3. An electronic oscillator comprising a pair of spaced elliptical cylindrical resonators and means connecting corresponding focal points of each resonator together and including means for producing a pair of electron streams, each of the respective streams when in operation forming a

substantially unidirectional coupling between a focal point in one of said resonators and a focal point in the second of said resonators.

4. An oscillator comprising two spaced flat, hollow, elliptical resonators, means adjacent focal points of said resonators to project an electron stream successively through one of said resonators at a focal point thereof into the other resonator at a corresponding focal point thereof, a shield surrounding the portion of the path of said electron stream between said resonators for shielding said electron stream from fluctuating electromagnetic fields in the space between said resonators and coupling means for electromagnetic waves connecting another pair of corresponding focal points of said resonators.

5. An oscillator comprising two flat, hollow, elliptical resonators, and a pair of means each connecting corresponding focal points of said resonators together and including means to project an electron stream successively through one of said resonators at a focal point thereof into the other resonator at a focal point thereof, said projecting means being oppositely directed with respect to the order in which the electron stream enters the respective resonators.

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