

Aug. 21, 1945.

A. H. RYAN

2,383,343

TWO-CYLINDER SHORT-WAVE RESONATOR APPARATUS

Filed Aug. 13, 1940

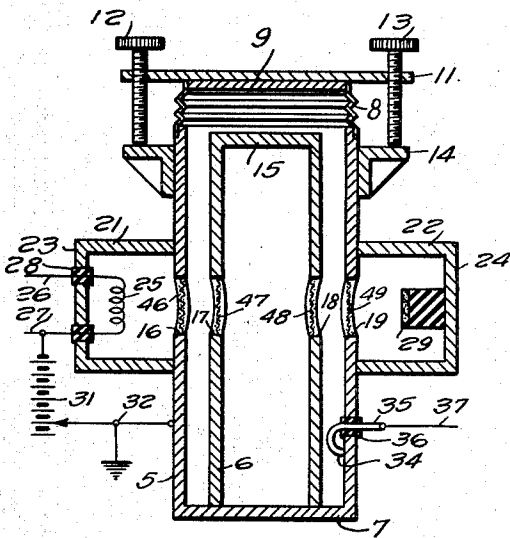


Fig. 1.

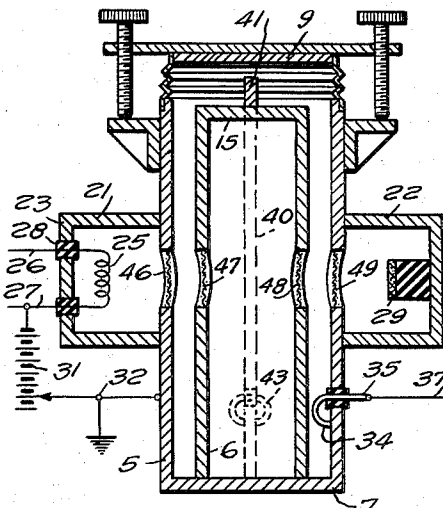


Fig. 2.

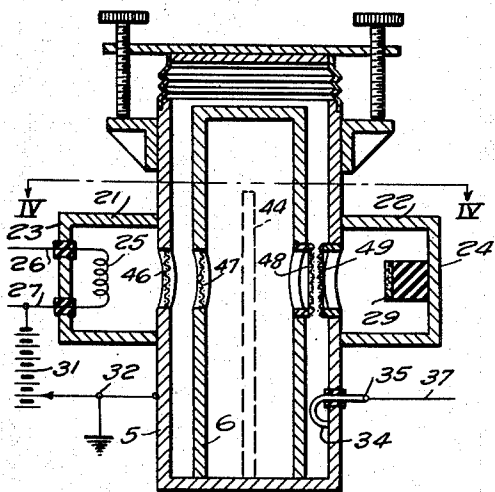


Fig. 3.

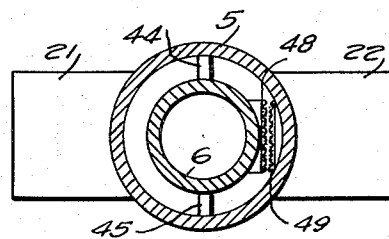


Fig. 4.

WITNESSES:

E. A. McLoskey.
Wm. C. Groom

INVENTOR

Alden H. Ryan.

BY O. R. Buchanan
ATTORNEY

UNITED STATES PATENT OFFICE

2,383,343

TWO-CYLINDER SHORT-WAVE
RESONATOR APPARATUS

Alden H. Ryan, Wilkinsburg, Pa., assignor to
Westinghouse Electric Corporation, East
Pittsburgh, Pa., a corporation of Pennsylvania

Application August 13, 1940, Serial No. 352,413

17 Claims. (Cl. 250—27.5)

For many purposes, in ultra-high-frequency work, the ability easily to change the frequency of hollow-conductor resonator-equipment, over a wide range of frequency-variations, is frequently extremely important, much more so than the efficiency of the apparatus. One example of such work is to be found in dielectric-measurements; another, in frequency-measurements; and still another, in military communications, where the ability to change the wave length easily is of great importance for reasons of secrecy. One of the difficulties in previous types of conductor-ensheathed hollow-body oscillators has resided in the difficulty of varying their wave lengths.

One of the objects of my invention, therefore, is to provide a new type of hollow-body resonator in which the wave length can be readily changed, and this new type of resonator is broadly useful, either with or without the frequency-varying adjustment, and either alone, or in combination with electron-stream apparatus for utilizing the resonator in an equipment in which the electron-stream is velocity-modulated.

Another of the objects of my invention is to provide a modified quarter-wave coaxial-cylinder resonator, or a resonator having two nested conducting cylinders of different diameters, disposed one within the other, both cylinders being closed at each end, and one cylinder being preferably shorter than the other, so that an end-space is provided which joins the annular resonating-spaces between the two cylinders. The resonating-spaces are so excited that the resonator can be utilized as a combined buncher and catcher in an electron-beam oscillator or amplifier of a type in which the beam passes diametrically through the four walls of the resonator in a line which is transverse to the axis.

A further object of my invention relates to means for very sensitively controlling the resonating frequency of such a resonator by providing minute adjustments in the length of the outer cylinder, or in the spacing between the spaced end-walls of the outer and inner cylinders, respectively, the apparatus being very sensitive, in its resonating frequency, to very small adjustments of this nature.

Further objects of my invention have to do with various constructional details and arrangements of the general type of apparatus already mentioned.

With the foregoing and other objects in view, my invention consists in the structures, apparatus, combinations, circuits and methods herein-

after described and claimed, and illustrated in the accompanying drawing, wherein:

Figures 1, 2 and 3 are longitudinal sectional views of three different forms of electron tubes embodying my invention; and

Fig. 4 is a transverse sectional view on the plane indicated by the line IV—IV in Fig. 3.

The illustrated forms of embodiment of my improved vacuum tube utilize an evacuated container comprising an outer metal cylinder 5 and an inner metal cylinder 6 of smaller diameter, disposed inside of the outer cylinder 5. One end of the device is provided with a metal end-portion 7 which is integrally or hermetically united to the outer cylinder 5, and which also constitutes an end-closure for the inner cylinder 6. The other end of the outer cylinder 5 is provided with a flexible-walled portion 8 which is joined onto an end-wall 9, so that said end-wall 9 may be adjusted in an axial direction with respect to the rest of the outer cylinder 5. The flexible-walled portion 8 is shown in the form of an accordion-pleated member having thin metal walls which are joined, with vacuum-tight joints, to the cylindrical wall 5 and the end-wall 9 respectively. The axial adjustment of the end-wall 9 is controlled by means of a cross-piece 11 which is adjusted by means of axially extending set-screws 12 and 13, abutting against suitable brackets 14 on the outer cylinder 5. The end of the inner cylinder 6, opposite to the end-wall 7, is provided with a separate end-closure wall 15 of its own, said end-closure wall 15 being spaced axially from the end-wall 9 of the outer cylinder 5.

In the form of invention shown in each of the figures, the four cylindrical wall-portions comprising both sides of the outer and inner cylinders 5 and 6, are provided with diametrically aligned openings 16, 17, 18 and 19, respectively, disposed in a line extending transversely with respect to the axis of the cylinders. In the illustrated form of embodiment, the line of the openings 16—19 is disposed approximately midway of the total length of the cylinder, corresponding to resonance-space oscillation in a fundamental mode of oscillation, although said line of openings 16—19 might be displaced in an off center relation, to correspond with a harmonic mode of oscillation in a manner which is described and claimed in my copending application Serial No. 352,411, filed August 13, 1940, for High-frequency apparatus utilizing harmonically-energized hollow-body resonators.

The diametrically aligned openings 16 and 19

in the outer cylinder 5 are covered by cylindrical metal protuberances 21 and 22, respectively, which are hermetically joined to the outer cylinder 5, at points surrounding the respective openings 16 and 19, said cylindrical protuberances 21 and 22 being closed, at their other ends, as by means of end-walls 23 and 24. The protuberance 21 is equipped with means for providing a source of emitted electrons, such as a filamentary cathode 25, said cathode having leads 26 and 27 which extend out through hermetically sealed insulating bushings 28 in the end-wall 23. The other protuberance 22 is preferably provided with an insulated floating electrode 29 of carbon or other material having a secondary electron emissivity ratio materially less than unity, for the purpose of dissipating the beam of electrons which flows from the filament 25, so as to prevent such beam from impinging concentratedly upon the end-wall 24 of the protuberance 22, as described and claimed in a copending application of G. L. Tawney, Serial No. 323,935, filed March 14, 1940, and assigned to the Westinghouse Electric & Manufacturing Company.

A suitable accelerating-field, for the electrons emitted from the element 25, is provided by means of a variable battery 31 which is connected between a ground connection 32 of the outer cylinder 5, and one of the terminal-leads 27 of the filament 25. As a result of this accelerating electrostatic field, the electrons emitted from the filament 25 are given an initial velocity whereby they enter the first opening 16 in the form of a beam of moving electrons, said opening 16 serving as a beam-focusing means, or any other more elaborate means being utilized, if desired, in accordance with known principles of electron-tube design. The beam of electrons then passes successively through the four diametrically aligned openings 16—19, and finally is dissipated on the walls 22—24 of the second protuberance 22. The first half of the resonating space between the two cylindrical members 5 and 6, that is, the space surrounding the intervening space between the first two openings 16 and 17, operates as a "buncher" for velocity-modulating the electrons of the beam as it passes through said intervening space from the opening 16 to the opening 17, such velocity-modulation resulting from the high-frequency electrostatic field resulting from the resonating oscillations and extending in the general direction of the electron-flow. After passing through this intervening space between the holes 16—17 of the buncher, the velocity-modulated electron-stream then passes diametrically across the inner cylinder 6, until it reaches the third hole or opening 18. The intervening space between the third and fourth holes 18 and 19 constitutes a part of a second resonating space which comprises the second half or portion of the space between the inner and outer cylinders 6 and 5.

In this second resonating space, high-frequency energy is absorbed from the electrons of the beam, which have become bunched in their traversal of the diameter of the inner cylinder 6, said bunching resulting from the alternate accelerations and decelerations which are imparted to the electron-stream by reason of the high-frequency oscillations of the buncher. The second resonating space, or half-portion of the total resonating space between the outer and inner cylinders 5 and 6, is thus utilized as a "catcher" wherein the oscillations are augmented from the high-frequency energy derived from the bunched electrons of the beam.

The strengthened oscillations of the catcher are tapped, by means of any suitable external-circuit coupling-means such as a half-loop 34 which terminates on the inside of the outer cylinder 5 and which has a conductor 35 which extends out through a vacuum-tight insulating sleeve 36, to join to an external output-circuit 37 of any kind.

In the form of my invention shown in Fig. 1, the resonating-spaces of the buncher and catcher merge into one another, both at the junctions of the annular spaces between the two cylinders, or rather the two halves of the annular space between the two cylinders 5 and 6, and also at the transverse end-space between the inner and outer end-walls 15 and 9. In this manner, the oscillations induced in the "catcher" half of the resonating space are directly transmitted to the "buncher" half of said space, thus constituting a certain feedback connection between the catcher and buncher, so that some of the energy of the catcher is returned to the buncher to further increase the velocity-modulation of the electron-stream.

In some cases it may be desirable to provide suitable baffle-means for the purpose of controlling the oscillation-modes, and to that end I contemplate that suitable baffles should be provided, as needed, either utilizing imperforate baffles or perforated baffles, with the baffles extending to any extent needed.

Thus in the form of my invention shown in Fig. 2, a longitudinally extending baffle 40 is provided, running in an axial direction, in the form of a metallic partition between the cylindrical walls of the inner and outer cylinders 6 and 5, and extending across the end 15 of the inner cylinder, as indicated at 41. Preferably, the end portion 41 of the baffle does not extend into contact with the end-plate 9 of the outer cylinder 5. In the form of my invention shown in Fig. 2, the buncher and catcher resonating spaces are thus fairly well segregated from each other by means of the baffle 40—41, and additional feedback-means may be provided in the form of half-loops 43 which are disposed in the magnetic fields of the two resonating spaces, and electrically joined together so as to couple said spaces together.

In the form of my invention shown in Figs. 3 and 4, two longitudinally extending shields 44 and 45 are provided on opposite sides of the inner cylinder 6, and extending between the inner cylinder and the outer cylinder 5, but extending less than the entire length of the inner cylinder 6, so that there may be no necessity for the special feedback coupling 43 which is shown in Fig. 2.

The four diametrically aligned openings 16, 17, 18 and 19 may be closed or covered by grids 46, 47, 48 and 49, respectively, said grids being diagrammatically illustrated as metal-wire screens, although it is intended that such illustration shall be symbolic of any open-work grid-structure such as is commonly known in the art of electron-tube design. I desire that the terms opening and grid shall be construed as synonymous with each other and interchangeable with each other, both terms being applicable either to a single opening or to a plurality of juxtapositioned openings.

In the form of embodiment of my invention which is shown in Figs. 3 and 4, I also show a construction in which the two grids 48 and 49 of the catcher are disposed more closely together, as measured in the line of movement of the electron-stream, than the corresponding grids 46 and

47 of the buncher. This is in accordance with a usually preferred constructional arrangement whereby the bunched electrons are caused to traverse the catcher more quickly than they do the buncher, thus enabling the catcher to the better absorb energy from the beam without running the risk of reducing the electron-velocity of some of the electrons to zero as the beam traverses the catcher.

In all of the forms of embodiment of my invention, simple adjustment of the set screws 12 and 13 serves to adjust the resonating frequency of the resonator over a wide frequency-variation, and thus serves as an exceedingly convenient tuning-means for the apparatus.

While I have shown my invention in three different forms of embodiment, and in particular, in forms of embodiment as an oscillator or high-frequency oscillation-generator, I desire it to be understood that the general principles of my invention are susceptible of considerable variation and adaptation, as various changes and modifications may be made by those skilled in the art in applying the invention to other uses. I desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language.

I claim as my invention:

1. An electron tube comprising an evacuated container; means therein for producing an electron-beam; a modulating beam-coupling means for operating on said electron-beam at a buncher-region thereof for modulating the electron-velocity of said beam at a predetermined high-frequency rate; an excitable beam-coupling means to be acted upon by said electron-beam at a catcher-region thereof for absorbing high-frequency energy from the modulations of said beam; means for providing an intermediate space between said buncher- and catcher-regions of the electron-beam, said intermediate space being of a drift-space length which causes the electrons to become bunched as a result of the velocity-modulation in said buncher-region, so that the electrons traverse said catcher-region in a substantially bunched condition; said modulating and excitable beam-coupling means being two different portions of a single, conductor-ensheathed hollow-body resonator, for passing the electron-beam successively first in operative relation to the beam-modulating portion and later in operative relation to the energy-absorbing portion of the resonating space of the resonator, said resonator comprising the two different portions of the resonating space in open-space communication with one another, sufficiently free of conducting partitions so that a high-frequency oscillating condition in the energy-absorbing portion of the resonating space will directly communicate a high-frequency oscillating condition to the beam-modulating portion of the resonating space; and coupling means for coupling the resonator to some external device.

2. An electron tube comprising an evacuated container; means therein for producing an electron-beam; means for providing first, second and third spaces to be successively traversed by said beam; said first and third spaces being two different portions of a single conductor-ensheathed hollow-body resonator, said second space being of a drift-space length which causes the electrons to become bunched as a result of velocity-modulation in said first space, so that the electrons traverse said third space in a substantially

bunched condition; the said resonator comprising two different portions of the resonating space in open-space communication with one another, sufficiently free of conducting partitions so that a high-frequency oscillating condition in said third-space portion of the resonating space will directly communicate a high-frequency oscillating condition to the first-space portion of the resonating space; and coupling means for coupling the resonator to some external device.

3. An electron tube comprising an evacuated container; means therein for producing an electron-beam; means for providing first, second, third and fourth spaces to be successively traversed by said beam; means adapted to be energized to produce a unidirectional potential-gradient for acting longitudinally upon said beam somewhere within said first space; said second and fourth spaces being two different portions of a single conductor-ensheathed hollow-body resonator, said third space being of a length which causes the electrons to become bunched as a result of velocity-modulation in said second space, so that the electrons traverse said fourth space in a substantially bunched condition; the two different portions of the resonating space of resonator being in open-space communication with one another, sufficiently free of conducting partitions so that a high-frequency oscillating condition in said fourth-space portion of the resonating space will directly communicate a high-frequency oscillating condition to the second-space portion of the resonating space; and coupling means within said resonator for coupling the internal oscillations within said resonator to some external device.

4. An electron tube comprising an evacuated container; means therein for providing a source of emitted electrons; four successively mounted spaced grids therein for providing a first intervening space between the first and second of said four grids, a second intervening space between the second and third of said four grids, and a third intervening space between the third and fourth of said four grids; said second space being of a length which causes the electrons to become bunched as a result of velocity-modulation in said first space, so that the electrons traverse said third space in a substantially bunched condition; an electron-beam-producing means, including means adapted to be energized to produce a potential-gradient somewhere in the space between the electron-source and the first of said four grids, for imparting an initial velocity to the electrons and for causing a beam of electrons to flow successively through the four aforesaid grids; a single conductor-ensheathed hollow-body resonator including said first and third intervening spaces as two different portions of the resonating space of said resonator, the two different portions of the resonating space of the resonator being in open-space communication with one another, sufficiently free of conducting partitions so that a high-frequency oscillating condition in the portion of the resonator including said third intervening space will directly communicate a high-frequency oscillating condition to the portion of the resonator including said first intervening space; and coupling means within said resonator for coupling the internal oscillations within said resonator to some external device.

5. An electron tube comprising: a two-cylinder hollow-conductor resonator-element comprising two cylindrical members of different di-

ameters, the larger cylindrical member being hollow and substantially closed at each end; the smaller cylindrical member being disposed within the larger cylindrical member and being smaller axially, as well as radially, than said larger cylindrical member; one end of the inner cylindrical member being spaced from the corresponding end of the outer cylindrical member; the four spaced cylindrical wall-portions of said two cylindrical members having substantially aligned openings lying in an approximately diametrical line spaced a considerable distance away from said spaced end of the inner cylindrical member and extending transversely with respect to the axis of said resonator-element; means providing an evacuated container including said two-cylinder hollow-conductor resonator-element and including a space surrounding each of said diametrically aligned openings in the outer cylindrical member; means for producing an electron-beam for passing successively through said four wall-openings within said evacuated container; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

6. An electron tube comprising: a two-cylinder hollow-conductor resonator-element comprising two cylindrical members of different diameters, the larger cylindrical member being hollow and substantially closed at each end; the smaller cylindrical member being disposed within the larger cylindrical member and being smaller axially, as well as radially, than said larger cylindrical member, one end of the inner cylindrical member being spaced from the corresponding end of the outer cylindrical member; the four spaced cylindrical wall-portions of said two cylindrical members having substantially aligned openings lying in an approximately diametrical line extending transversely with respect to the axis of said resonator-element at a point substantially midway of the length thereof; means providing an evacuated container including said two-cylinder hollow-conductor resonator-element and including a space surrounding each of said diametrically aligned openings in the outer cylindrical member; means for producing an electron-beam for passing successively through said four wall-openings within said evacuated container; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

7. An electron tube comprising: a two-cylinder hollow-conductor resonator-element comprising two cylindrical members of different diameters, the larger cylindrical member being hollow and having vacuum-tight end-walls, the smaller cylindrical member being disposed within the larger one; the four spaced cylindrical wall-portions of said two cylindrical members having substantially aligned openings lying in an approximately diametrical line transverse with respect to the axis; enclosure-means, including said hollow larger cylindrical member, and also including vacuum-tight hollow protuberances over said openings in said hollow larger cylindrical member, providing an evacuated vacuum-tight container for said electron tube; means for producing an electron-beam for passing successively through said four wall-openings within said evacuated container; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

8. An electron tube comprising: a two-cylinder

der hollow-conductor resonator-element comprising two cylindrical members of different diameters, the larger cylindrical member being hollow and substantially closed at each end; the smaller cylindrical member being disposed within the larger one; the four spaced cylindrical wall-portions of said two cylindrical members having substantially aligned openings lying in an approximately diametrical line transverse with respect to the axis; means providing an evacuated container including said two-cylinder hollow-conductor resonator-element and including a space surrounding each of said diametrically aligned openings in the outer cylindrical member; means for producing an electron-beam for passing successively through said four wall-openings within said evacuated container; the distance between the two wall-openings of the inner cylindrical member being of a length which causes the electrons to become bunched as a result of velocity-modulation in the preceding space between the two cylindrical members; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

9. An electron tube comprising: a two-cylinder hollow-conductor resonator-element comprising two cylindrical members of different diameters, the larger cylindrical member being hollow and substantially closed at each end, the smaller cylindrical member being disposed within the larger one; the four spaced cylindrical wall-portions of said two cylindrical members having substantially aligned openings lying in an approximately diametrical line transverse with respect to the axis; a grid across each of said four wall-openings; the last two grids being spaced a shorter distance apart than the first two grids; means providing an evacuated container including said two-cylinder hollow-conductor resonator-element and including a space surrounding each of said diametrically aligned openings in the outer cylindrical member; means for producing an electron-beam for passing successively through said four wall-openings within said evacuated container; the second and third grids being spaced by a distance which causes the electrons to become bunched as a result of velocity-modulation in the space between the first two grids; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

10. An electron tube comprising: a two-cylinder hollow-conductor resonator-element comprising two cylindrical members of different diameters, the larger cylindrical member being hollow and substantially closed at each end, the smaller cylindrical member being disposed within the larger one; the four spaced cylindrical wall-portions of said two cylindrical members having substantially aligned openings lying in an approximately diametrical line transverse with respect to the axis; two longitudinally disposed conducting partitions disposed across some of the space between the inner and outer cylindrical members on diametrically opposite sides of the two-cylinder hollow-conductor resonator element approximately in a plane transverse with respect to the diametrical line of said four wall-openings; means providing an evacuated container including said two-cylinder hollow-conductor resonator-element and including a space surrounding each of said diametrically aligned openings in the outer cylindrical member; means for producing an electron-beam for passing succes-

sively through said four wall-openings within said evacuated container; the distance between the two wall-openings of the inner cylindrical members being of a length which causes the electrons to become bunched as a result of velocity-modulation in the preceding space between the two cylindrical members; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

11. An electron tube comprising: a two-cylinder hollow-conductor resonator-element comprising two cylindrical members of different diameters, the larger cylindrical member being hollow and substantially closed at each end, the smaller cylindrical member being disposed within the larger one; the four spaced cylindrical wall-portions of said two cylindrical members having substantially aligned openings lying in an approximately diametrical line transverse with respect to the axis; two longitudinally disposed conducting partitions disposed across the major portion of the space between the inner and outer cylindrical members on diametrically opposite sides of the two-cylinder hollow-conductor resonator element approximately in a plane transverse with respect to the diametrical line of said four wall-openings, a coupling feedback means for coupling the internal oscillations in the resonating spaces on the two sides of said longitudinally disposed partitions; means providing an evacuated container including said two-cylinder hollow-conductor resonator-element and including a space surrounding each of said diametrically aligned openings in the outer cylindrical member; means for producing an electron-beam for passing successively through said four wall-openings within said evacuated container; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

12. An electron tube comprising: a two-cylinder hollow-conductor resonator-element comprising two cylindrical members of different diameters, the larger cylindrical member being hollow and substantially closed at each end, the smaller cylindrical member being disposed within the larger one and having one end-closure wall spaced from the end-closure wall of the larger cylindrical member at one end of the two-cylinder hollow-conductor resonator-element whereby the two halves of the resonating space are joined together by a transverse space at said end; the four spaced cylindrical wall-portions of said two-cylindrical members having substantially aligned openings lying in an approximately diametrical line transverse with respect to the axis; means providing an evacuated container including said two-cylinder hollow-conductor resonator-element and including a space surrounding each of said diametrically aligned openings in the outer cylindrical member; means for producing an electron-beam for passing successively through said four wall openings within said evacuated container; the distance between the two wall-openings of the inner cylindrical member being of a length which causes the electrons to become bunched as a result of velocity-modulation in the preceding space between the two cylindrical members; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

13. An electron tube comprising: a two-cylinder hollow-conductor resonator-element comprising two cylindrical members of different di-

ameters, the larger cylindrical member being hollow and substantially closed at each end, the smaller cylindrical member being disposed within the larger one and having one end-closure wall spaced from the end-closure wall of the larger cylindrical member at one end of the two-cylinder hollow-conductor resonator-element whereby the two halves of the resonating space are joined together by a transverse space at said end, an externally controllable movable means connected to said end of the resonator for adjusting the effective capacity between said spaced end-closure walls of the inner and outer cylindrical members; the four spaced cylindrical wall-portions of said two cylindrical members having substantially aligned openings lying in an approximately diametrical line transverse with respect to the axis; means providing an evacuated container including said two-cylinder hollow-conductor resonator-element and including a space surrounding each of said diametrically aligned openings in the outer cylindrical member; means for producing an electron-beam for passing successively through said four wall-openings within said evacuated container; the distance between the two wall-openings of the inner cylindrical member being of a length which causes the electrons to become bunched as a result of velocity-modulation in the preceding space between the two cylindrical members; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

14. An electron tube comprising: a two-cylinder hollow-conductor resonator-element comprising two cylindrical members of different diameters, the larger cylindrical member being hollow and substantially closed at each end, the smaller cylindrical member being disposed within the larger one and having one end-closure wall spaced from the end-closure wall of the larger cylindrical member at one end of the two-cylinder hollow-conductor resonator-element, means movably joining the outer one of said spaced end-closure walls to the cylindrical wall-portion of the outer cylindrical member whereby it can be moved in a substantially axial direction with respect to said two-cylinder hollow-conductor resonator-element; the four spaced cylindrical wall-portions of said two cylindrical members having substantially aligned openings lying in an approximately diametrical line transverse with respect to the axis; means providing an evacuated container including said two-cylinder hollow-conductor resonator-element and including a space surrounding each of said diametrically aligned openings in the outer cylindrical member; means for producing an electron-beam for passing successively through said four wall-openings within said evacuated container; the distance between the two wall-openings of the inner cylindrical member being of a length which causes the electrons to become bunched as a result of a velocity-modulation in the preceding space between the two cylindrical members; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

15. An electron tube comprising: a two-cylinder hollow-conductor resonator-element comprising two cylindrical members of different diameters, the larger cylindrical member being hollow and substantially closed at each end, the smaller cylindrical member being disposed within the larger one and having one end-closure wall

spaced from the end-closure wall of the larger cylindrical member at one end of the two-cylinder hollow-conductor resonator-element whereby the two halves of the resonating space are joined together by a transverse space at said end; means movably joining one of the end-wall portions of said two-cylinder hollow-conductor resonator-element to a cylindrical wall-portion thereof whereby said end-wall portion can be moved in a substantially axial direction with respect to said two-cylinder hollow-conductor resonator-element; the four spaced cylindrical wall-portions of said two cylindrical members having substantially aligned openings lying in an approximately diametrical line transverse with respect to the axis; means providing an evacuated container including said two-cylinder hollow-conductor resonator-element and including a space surrounding each of said diametrically aligned openings in the outer cylindrical member; means for producing an electron-beam for passing successively through said four wall-openings within said evacuated container; the distance between the two wall-openings of the inner cylindrical member being of a length which causes the electrons to become bunched as a result of velocity-modulation in the preceding space between the two cylindrical members; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

16. An electron tube comprising: a two-cylinder hollow-conductor resonator-element comprising two cylindrical members of different diameters, the larger cylindrical member being hollow and substantially closed at each end, the smaller cylindrical member being disposed within the larger one and having one end-closure wall spaced from the end-closure wall of the larger cylindrical member at one end of the two-cylinder hollow-conductor resonator-element whereby the two halves of the resonating space are joined together by a transverse space at said end; said inner and outer cylindrical members being of metal, one section of the cylindrical wall-portion of the outer cylindrical member including an expansible and contractible, vacuum-tight, flexible-walled metallic part; the four spaced cylindrical wall-portions of said two cylindrical members having

substantially aligned openings lying in an approximately diametrical line transverse with respect to the axis; means providing an evacuated container including said two-cylinder hollow-conductor resonator-element and including a space surrounding each of said diametrically aligned openings in the outer cylindrical member, means for producing an electron-beam for passing successively through said four wall-openings within said evacuated container; the distance between the two wall-openings of the inner cylindrical member being of a length which causes the electrons to become bunched as a result of velocity-modulation in the preceding space between the two cylindrical members; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

17. An electron tube comprising: a two-cylinder hollow-conductor resonator-element comprising two cylindrical members of different diameters, the larger cylindrical member being hollow and substantially closed at each end, the smaller cylindrical member being disposed within the larger one; the four spaced cylindrical wall-portions of said two cylindrical members having substantially aligned openings lying in an approximately diametrical line transverse with respect to the axis; a plurality of longitudinally and approximately radially disposed conducting partitions between the inner and outer cylindrical members; means providing an evacuated container including said two-cylinder hollow-conductor resonator-element and including a space surrounding each of said diametrically aligned openings in the outer cylindrical member; means for producing an electron-beam for passing successively through said four wall-openings within said evacuated container; the distance between the two wall openings of the inner cylindrical members being of a length which causes the electrons to become bunched as a result of velocity-modulation in the preceding space between the two cylindrical members; and coupling means for coupling to the internal oscillations within said two-cylinder hollow-conductor resonator-element.

ALDEN H. RYAN.