Aug. 7, 1945. G. L. TAWNEY 2,381,320

ELECTROMAGNETIC APPARATUS

Filed Nov. 28, 1940

Fig. 1.

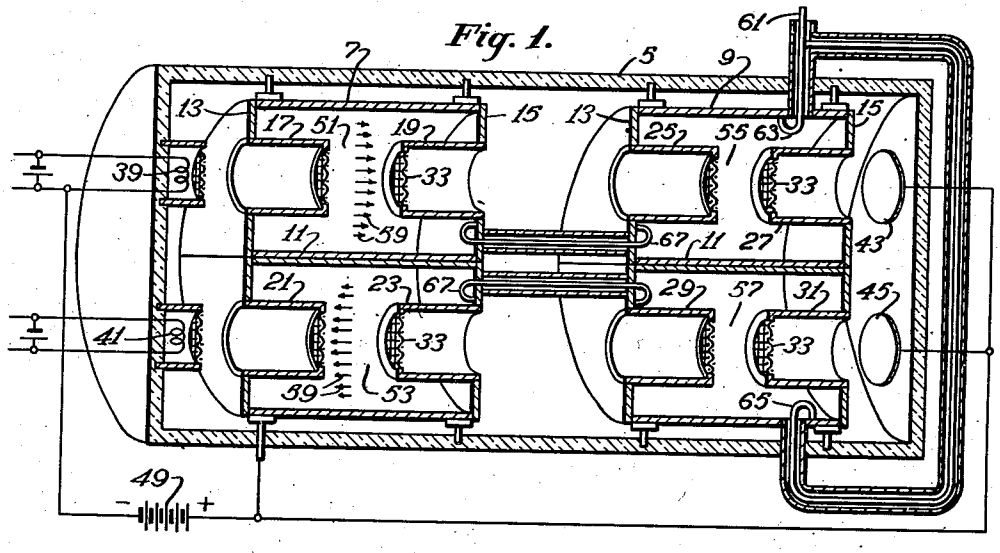


Fig.2.

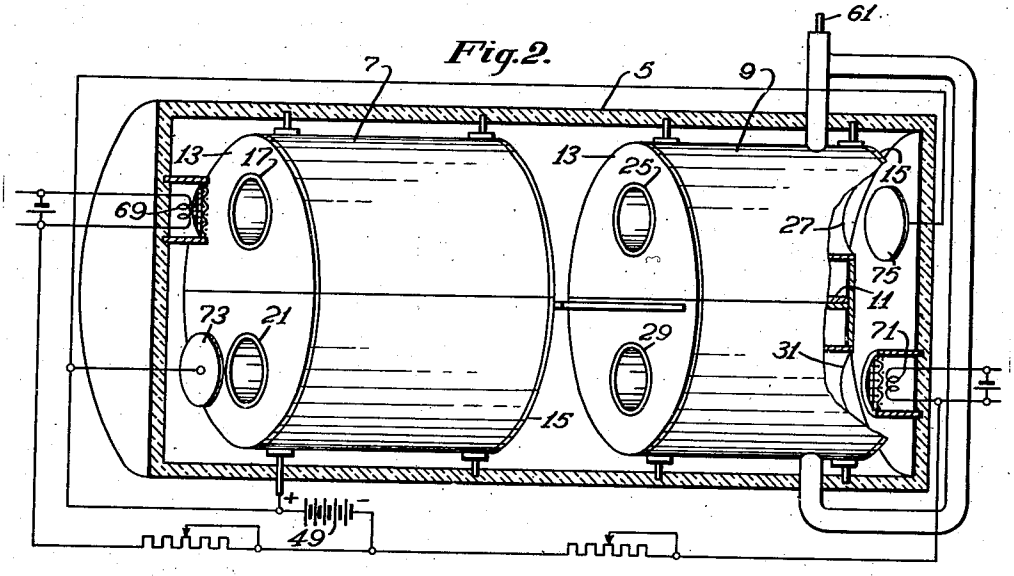
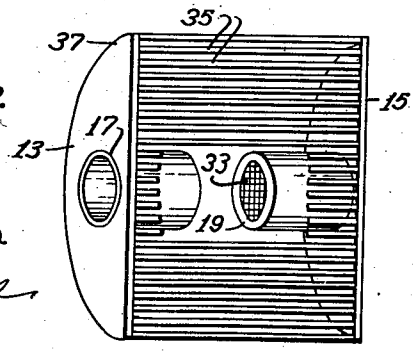


Fig.3.



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ELECTROMAGNETIC APPARATUS

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8 Claims. (Cl. 250—27.5)

My invention relates to apparatus for producing electromagnetic phenomena and has particular relation to systems for generating, modifying, or utilizing high-frequency electromagnetic waves.

Hollow body resonators perform an important function in the production of phenomena involving a ultra-high-frequency radiation having a wave length of the order of decimeters. The dimensions of a resonator determine the wave length of the radiant energy with which it is resonant. If very high-frequency radiation is involved, a small resonator is, in accordance with the teachings of the prior art of which I am aware, used. The alignment and mounting of small hollow bodies so that they function as resonators is a difficult matter. Moreover, the frequency range over which hollow body resonators may be used is limited on the higher frequency side by the physical limitations involved in the construction of a small hollow body.

In the case of short wave electromagnetic radiation efficiency is also an important consideration. The efficiency of a resonator as a function of its dimensions is dependent on a quantity, Q, which may be computed from the relationship equation

$$Q=\frac{2\delta\int H^2dv}{\int H^2ds}$$

where δ, (commonly called the "skin depth") is a quantity determined from the thickness to which the field penetrates into the surface of the resonator, H is the magnetic field vector, v is a volume coordinate and s is a surface coordinate. The efficiency of a hollow body resonator is thus roughly dependent on the ratio of the volume to the surface, and, therefore, decreases roughly as its linear dimension is decreased.

It is, accordingly, an object of my invention to provide a resonator for the generation, modification or utilization of electromagnetic waves of very high frequency.

Another object of my invention is to provide an efficient resonator, the resonant frequency of which is very high.

A specific object of my invention is to provide a generator or an amplifier for electromagnetic radiation of very high frequency.

More concisely stated, it is an object of my invention to provide an efficient ultra-high-frequency generator or amplifier in which hollow body resonators are frequency determining elements.

In accordance with my invention, I provide a conducting barrier determining a potential node in a hollow body resonator having convenient dimensions. The frequency at which the resonator may be excited to oscillate thus corresponds to a harmonic of the fundamental frequency of the resonator. A resonator of convenient dimensions with properly positioned node determining barriers may be excited to oscillate at a relatively high frequency. The Q function for a resonator of this type is dependent on the dimensions of the complete hollow body and, therefore, is substantial in spite of the fact that the resonant frequency may be high.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of specific embodiments when read in connection with the accompanying drawing, in which:

Figure 1 is a diagrammatic view partly in section and partly in perspective showing an embodiment of my invention;

Fig. 2 is a diagrammatic view partly in perspective and partly in section showing a modification of my invention; and

Fig. 3 is a view in perspective showing a portion of a resonator in accordance with a further modification of my invention.

While my invention is shown in the drawing as applied to an ultra short wave oscillator, it is also applicable to an amplifier or in any other device for modifying, utilizing or generating high frequency electromagnetic radiation. The apparatus shown in Fig. 1 comprises an evacuated cylindrical container 5 of insulating material within which a plurality of hollow cylindrical shells 7 and 9 of substantially the same dimensions is mounted. The shells 7 and 9 are mounted centrally within the container 5 with their axes coextensive and coincident with the axis of the container. The space within each shell is subdivided by a metal partition 11 which extends along a central symmetric plane. The bases 13 and 15 of the shells have centrally disposed circular openings on both sides of the partitions 11 and reentrant tubes 17, 19, 21, 23, 25, 27, 29 and 31 extend into the openings. The internal ends of the tubes are spaced a relatively short distance and are covered by an openwork 33. The shells are so mounted that the reentrant tubes 17, 19, 25 and 27 and 21, 23, 29

and 31 above and below the partition, respectively, are aligned.

Under certain circumstances, the solid partition subdividing the shells may be replaced by an array of bars 35, as in the half-shell 37 illustrated in Fig. 3. The bars 35 or the partition 11 need not, of course, be arranged along a straight line. They may, for example, trace a circle coaxial with the cylinder or have any other configuration. The shells need not necessarily be subdivided by single partitions. Under certain circumstances several partitions may be inserted. The subdividing elements need not extend along symmetric lines or symmetric planes of the shell. They should, however, coincide with the natural nodes corresponding to the electromagnetic harmonics of the resonator. While hollow shells are to be preferred, the space within the shells may under certain circumstances be filled wholly or in part with a suitable insulating material.

A plurality of electron emitting filaments 39 and 41 are mounted in one end of the container 5. In the opposite end of the container a plurality of collecting electrodes 43 and 45 is mounted. The geometric centers of one of the filaments 39 and one of the electrodes 43 lie on the axes of one set of aligned reentrant tubes 17, 19, 25 and 27 and the centers of the other filament 41 and collecting electrode 45 lie on the axes of the other set of tubes 21, 23, 29 and 31. A potential is impressed between the collecting electrodes 43 and 45 and the filaments 39 and 41 from a source 49 and electron streams emitted from the filaments flow through the reentrant tubes with which they are aligned. Preferably, fine electron streams are desired and for this reason suitable apertures and constricting grids are provided for each of the filaments 39 and 41. Since the apertures and grids do not concern the present invention and are well known in the cathode ray tube art and the general electronic art, they are not shown and described in detail. Any suitable electron stream focusing system available in the cathode ray tube art may be used.

Each electron stream passes through the openwork ends 33 of the respective reentrant tubes 21 to 31 with which it is aligned and is subject to the electromagnetic fields in the gaps 51 and 53, and 55 and 57 within the subdivisions of the shells 7 and 9, respectively, formed by the partitions 11 as it passes between the ends of the tubes 17 and 19 and 21 and 23, and 25 and 27 and 29 and 31, respectively.

The distance between the ends 33 of the reentrant tubes 21 to 31 in each of the shells 7 and 9 is short compared to the wave length to which the subdivisions of the shells are resonant.

In passing through the gaps 51 and 53 of the first shell 7 in their path, the electron streams are subjected to the electric field vector of the high-frequency electromagnetic field with which the corresponding subdivisions of the shell are resonant. The field is periodic and has a frequency determined by the dimensions of the subdivisions of the resonator 7. The space distribution of the field at any instant is illustrated by the array of arrows 59 in the shell. The field has nodal regions in the external wall of the shell and in the partition. Between the nodal points the field varies as an oscillating function. The polarity of the field in one division of the shell is opposite to that in the adjacent subdivision. Because the reentrant tubes 17 and 19 and 21 and 23 are centrally mounted with respect to the shell wall and the partition, the field is a maximum in the gaps 51 and 53.

As the streams pass through the gaps 51 and 53, the fields in the gaps impress a periodic component on the velocity of their electrons. Because the velocity of electrons leaving the gaps at different instants varies periodically, the electrons in each of the streams alternately accumulate in bunches and separate as they advance. The gaps 55 and 57 between the reentrant tubes 25 and 27 and 29 and 31, respectively, of the second shell 9 are so spaced from the corresponding gaps 51 and 53 in the first shell 7 that the electrons are grouped in bunches when they pass through the former gaps. The field having the same frequency as the distance between the gaps 51 and 55 and 53 and 57 is so related to the electron speed that when the electrons reach the gaps 55 and 57, the fields in the gaps have a polarity such that they oppose the forward motion of the electrons. The fields in the gaps 55 and 57 absorb energy from the electron streams. The energy may be radiated by an antenna 61 extending from loops 63 and 65 properly oriented to be threaded by the magnetic field within the subdivisions of the shell 9. The loops 63 and 65 in the two subdivisions of the shell face in opposite directions because the magnetic fields by which they are threaded are of opposite polarity and it is desired that the electromotive forces induced in the loops shall add and not counteract each other. Sufficient energy for modifying the electron speed is supplied to the modulating shell 7 from the radiating shell 9 by interconnected coupling loops 67 interconnected by a conductor.

In accordance with the preferred practice of my invention an electron stream should be associated with each of the subdivisions of the shells 7 and 9. In lieu of a plurality of streams a single stream may be used. For example, the lower filament 41 in the oscillator shown in Fig. 1 may be maintained deenergized and only the upper filament used to transfer the energy from the source 49 to the antenna 61.

Filaments 69 and 71 and collecting electrodes 73 and 75 may also be disposed at opposite ends of the container 5, as shown in Fig. 2. In this case each of the shells 7 and 9 functions both as a modulator for the electron velocity and as an energy deriving device, one shell being a modulator for one stream and an energy deriving resonator for the other while the other shell is an energy deriving resonator for the first stream and a modulator for the second stream. Since there is an interchange of energy between the two shells through the electron streams in the Fig. 2 arrangement, no coupling loop need be utilized. In oscillators of the type shown in Fig. 2, the subdividing barrier should preferably be of the type shown in Fig. 3 with the bars spaced closely. The close spacing is desirable because the velocity modulating energy should be relatively small and the energy of the absorbing region relatively large. The bars when closely spaced permit sufficient leakage between the subdivisions of each of the shells for modulating purposes.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the spirit of the appended claims.

I claim as my invention:

1. An electron tube comprising a first electromagnetic resonator including a first conducting

shell having conducting means positioned therein subdividing the space bounded by said first shell, a plurality of electrodes mounted outside of said first shell for projecting a stream of electrical charges through one subdivision of said space bounded by said first shell, and a second electromagnetic resonator comprising a second conducting shell having second conducting means therein subdividing the space bounded by said second shell, one of the subdivisions of said second shell having the same resonant frequency as said one subdivision of said first shell, said second shell being mounted with said one subdivision thereof in the path of said stream between said first shell and one of said electrodes whereby said stream passes through said one subdivision of said second shell after it has passed through the subdivision of said first shell.

2. An electron tube comprising an electromagnetic resonator including a conducting shell having conducting means therein subdividing the space bounded by said shell, a plurality of electrodes mounted outside of said shell for projecting a stream of electrical charges through one subdivision only of said space, said conducting means being positioned parallel to the path of said stream and means positioned along the path of said stream beyond said subdivision for producing an electromagnetic field in the path of said stream whereby said charges enter said field after passing through said subdivision.

3. An electron tube comprising a first electromagnetic resonator including a first conducting shell having a plane of symmetry and conducting means within said first shell and lying substantially in said plane subdividing the space bounded by said first shell, a plurality of electrodes mounted outside of said first shell for projecting a stream of electrical charges through one subdivision of said space bounded by said first shell, said conducting means being parallel to the path of said stream and a second electromagnetic resonator comprising a second conducting shell having second conducting means therein subdividing the space bounded by said second shell, one of the subdivisions of said second shell having the same resonant frequency as said one subdivision of said first shell, said second shell being mounted with said one subdivision thereof in the path of said stream between said first shell and one of said electrodes whereby said stream passes through said one subdivision of said second shell after it has passed through the subdivision of said first shell.

4. An electron tube comprising a first electromagnetic resonator including a first conducting shell having conducting means positioned therein subdividing the space bounded by said first shell, a plurality of electrodes mounted outside of said first shell for projecting a stream of electrical charges through one subdivision of said space, said conducting means being positioned parallel to the path of said stream, a second electromagnetic resonator comprising a second conducting shell having second conducting means therein subdividing the space bounded by said second shell, one of the subdivisions of said second shell having the same resonant frequency as said one subdivision of said first shell, said second shell being mounted with said one subdivision thereof in the path of said stream between said first shell and one of said electrodes whereby said stream passes through said one subdivision of said second shell after it has passed through said one subdivision of the first shell, and means connected to said shells electromagnetically coupling said one subdivision of the first shell and said one subdivision of the second shell whereby said first resonator introduces a periodic change in the motion of said charges, said second shell being spaced from said first shell to receive the charges selectively and absorb energy from them.

5. An electron tube comprising an electromagnetic resonator including a conducting shell having conducting means therein subdividing the space bounded by said shell, first electrode means mounted outside of said shell for projecting a first stream of electrical charges through one of said subdivisions, said conducting means being positioned parallel to the path of said stream, second electrode means mounted outside of said shell for projecting a second stream of electrical charges through a second of said subdivisions, means positioned along the path of said first stream beyond said first subdivision for producing an electromagnetic field in the path of said first stream having a frequency resonant with said first subdivision, and means positioned along the path of said second stream beyond said second subdivision for producing an electromagnetic field in the path of said second stream having a frequency resonant with said second subdivision.

6. An electron tube comprising an electromagnetic resonator including a conducting shell having conducting means therein subdividing the space bounded by said shell, electrode means mounted outside said shell for projecting a stream of electrical charges through one subdivision only of the space bounded by said shell, said conducting means being positioned parallel to the path of said stream, and energy extracting means beyond said resonator and in the path of said stream coupled with the interior of said subdivision for producing an electromagnetic field therein having a frequency at which said subdivision is resonant to modulate the velocity of said stream of charges.

7. An electron tube comprising an electromagnetic resonator including a conducting shell having a plane of symmetry and conducting means lying substantially in said plane within said shell subdividing the space bounded thereby, electrode means mounted outside said shell for projecting a stream of electrical charges through one subdivision only of said space, said conducting means being positioned parallel to the path of said stream, and energy extracting means positioned in the path of said stream beyond said resonator for effecting the production of an electromagnetic field therein having a frequency at which said subdivision is resonant to modulate the velocity of said stream of charges.

8. An electron tube comprising an electromagnetic resonator including a conducting shell having a mode of oscillation and having apertures therein defining an electron path conducting bars positioned within said shell substantially parallel to the direction of said path and subdividing the space bounded by said shell, electrode means mounted outside said shell for projecting a stream of electrical charges along said path through one subdivision only of said space, and means positioned in the path of said stream beyond said resonator for effecting the production of an electromagnetic field therein having a frequency at which said subdivision is resonant to modulate the velocity of said stream of charges.

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