

Oct. 15, 1946.

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2,409,224

OSCILLATOR

Filed Oct. 23, 1941

FIG. 1

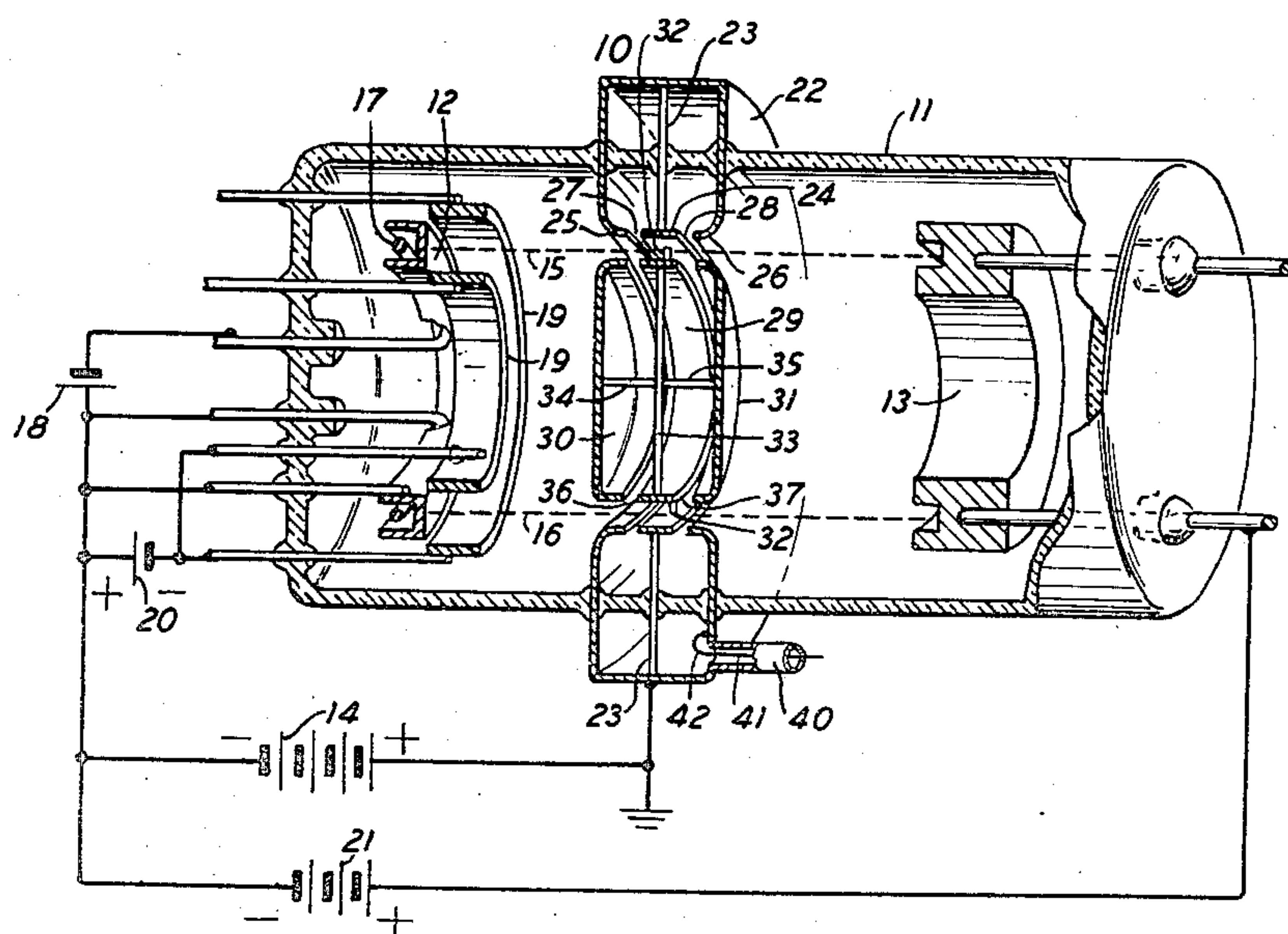
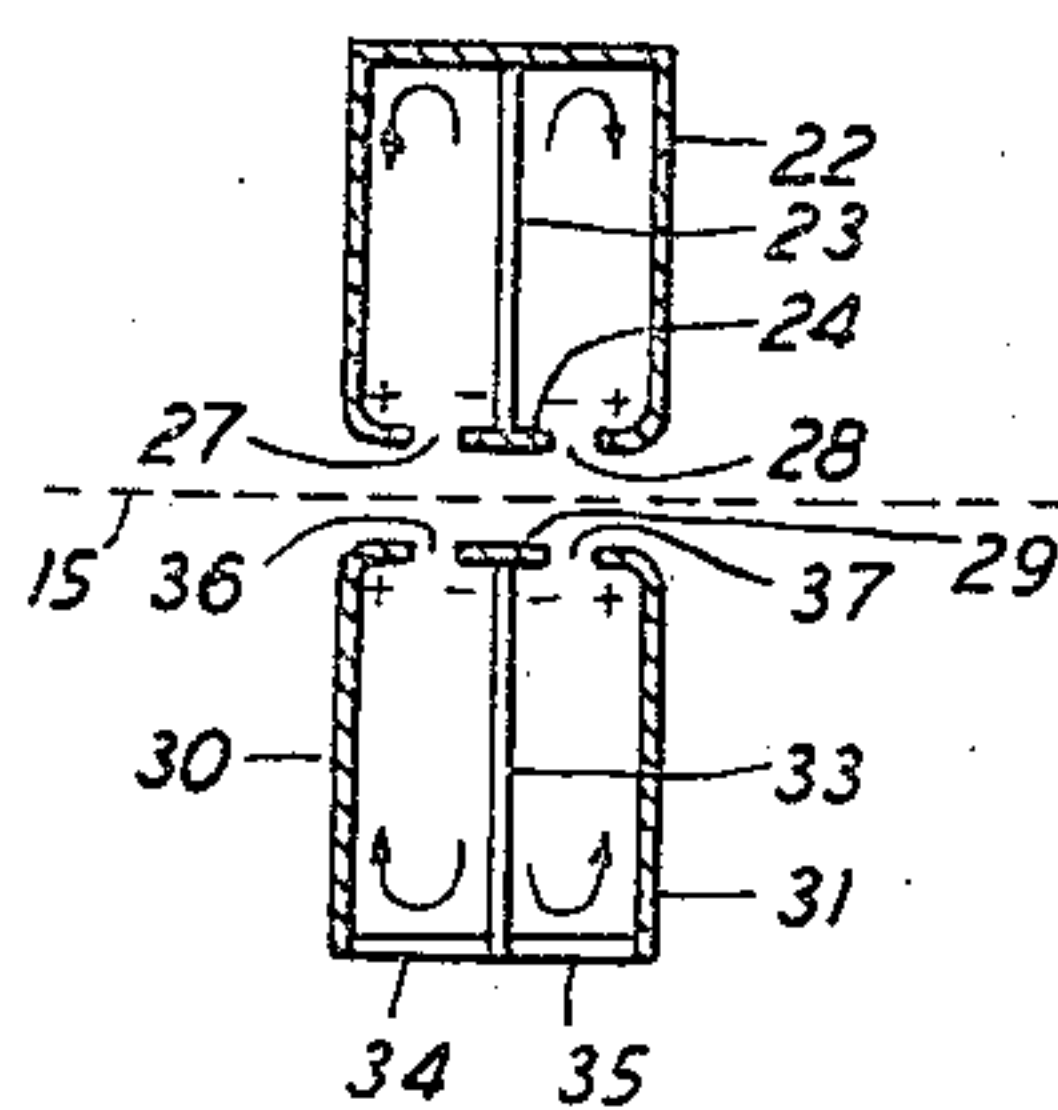


FIG. 2



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2,409,224

OSCILLATOR

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Application October 23, 1941, Serial No. 416,176

6 Claims. (Cl. 315-5)

1

This invention relates to electromagnetic oscillators for generating waves of ultra-high frequencies, for example, in the wave-length range of a few centimeters or less. More particularly, the oscillator is of the type involving an energy reaction between a stream of charged particles such as electrons, and an electromagnetic field within a resonating chamber.

An object of the invention is to produce a relatively large power output at extremely high frequencies employing only moderately high voltages.

Another object of the invention is to reduce the length of an electron discharge device in an ultra-high frequency oscillator thereby also reducing the bulk, weight and cost of such devices.

A further object of the invention is to reduce the size and complexity of the focussing equipment necessary in the operation of an electron beam oscillator.

A feature of the invention is the use of a mode of operation permitting a relatively short drift space corresponding, for example, to a quarter cycle transit time of the electrons. Another feature is the use of a compact resonating chamber which accommodates a tubular shaped electron beam.

Other objects and features of the invention will be apparent from the following description considered in conjunction with the accompanying drawing, while the scope of the invention is defined in the appended claims.

In the drawing:

Fig. 1 is a perspective view, partly in section, of an electron discharge device embodying the invention; and

Fig. 2 is a schematic diagram useful in explaining the mode of operation of the arrangement shown in Fig. 1.

In the arrangement of Fig. 1, a hollow resonating system 10 with conductive walls is fused into and partially enclosed by the envelope 11 of an electron discharge device. The resonating system 10 is positioned between an annular cathode 12 and a collector 13. The cathode 12, when heated, emits electrons which may be drawn out into a beam, tubular in shape, accelerated by a potential difference between the resonating structure 10 and the cathode 12. The potential difference may be maintained by a battery 14 or other suitable source, the positive terminal of the source being connected to the resonating system. A pair of rays near the center of the beam in the plane of the drawing are indicated by

2

dotted lines 15 and 16 which pass through an annular slot in the resonating system 10 and terminate in an annular groove in the collector 13.

A circular filament 17 is provided for heating the cathode 12 and may in turn be energized by a battery 18. Focussing plates 19 may be positioned near the cathode 12 on either side of the beam and may be polarized, preferably to a negative potential with respect to the cathode, by means of a battery 20. The collector 13 may be polarized to a positive potential somewhat less than the potential of the resonating system 10 by means of a battery 21, thus providing for the collection of spent electrons with relatively low energy dissipation. It will be understood that any or all of the batteries shown may be replaced by other suitable sources of electromotive force.

The resonating system 10 comprises a conductive outer toroidal shell 22 which is shown supported by the envelope 11, and is preferably grounded, as shown. Mechanically supported by and conductively connected to the shell 22 by a plurality of conductive rods 23 is a circular conductive band 24 separated from the flanged edges 25 and 26 of the shell 22 to form annular gaps 27 and 28 respectively. The rods 23 should be radial and positioned in the central plane of symmetry of the shell 22 and may be uniformly spaced about the circumference of the shell 22.

A subassembly comprising a conductive band 29 and a pair of conductive flanged disc members 30 and 31 all of slightly smaller diameter than the band 24, is positioned centrally with respect to the shell 22 and band 24 by spacers 32. A diametral conductive rod 33 inside the band 29 has attached to it a pair of central axial conductive rods 34 and 35 which in turn support the members 30 and 31, respectively with small clearances forming gaps 36 and 37 or annular slits between the members 30, 31 and the band 29. Fig. 2 shows a typical cross sectional view of the resonating system. It will be understood that various arrangements of the supporting and connecting rods are feasible without detriment to the operation of the system and such arrangements will readily occur to those skilled in the art.

In the operation of the system of Fig. 1, when the heating and polarizing sources are properly adjusted, a tubular beam of moving electrons passes through the large annular slot in the resonating system and by virtue of the gaps 27, 28, 36 and 37 the electrons of the beam are caused to interact with any electromagnetic field which may exist in the interior of the resonating system

10. It will be assumed that an electromagnetic standing wave pattern has been set up in the resonating system and that the wave is of such a type that it is accompanied by surface currents which at a given moment are flowing in the directions indicated by arrows in Fig. 2. These currents will evidently produce relative potentials at the edges of the gaps 27, 28, 36 and 37 according to the scheme indicated by the plus and minus signs in Fig. 2, gaps 27 and 36 having positive charges at the left and negative charges at the right and gaps 28 and 37 having negative charges at the left and positive charges at the right. An electron following a path along the ray 15 from left to right will be decelerated in passing the gaps 27 and 36. An electron passing at a later instant when the current is reversing will have its velocity unchanged. An electron arriving still later when the currents are in the direction opposite to those shown by the arrows in Fig. 2, will be speeded up in passing the gaps 27 and 36. As the stream of electrons, some speeded up and others slowed down and still others with speed unchanged, passes between the bands 24 and 29, the electrons will be substantially shielded from the alternating electromagnetic field and, being carried forward according to their varying velocities, will tend to be gathered together into groups or bunches. More particularly, the electrons which have been speeded up will tend to overtake other electrons ahead of them which have been slowed down, the concentration of electrons thus formed having approximately at its center an electron whose velocity has not been changed. Similar groups of electrons will follow the one under consideration and between groups the electrons will be relatively sparse. Each group of electrons emerging from between the bands 24 and 29 and passing the gaps 28 and 37 will react with the electromagnetic field, being speeded up or slowed down or left with unchanged velocity according to the phase of the field at the time of passage of the group. If the electrons of the group are slowed down by the field, they give up some of their kinetic energy to the field and the energy transferred tends to maintain the oscillations of the field. By proper timing of the transit of the electrons in the field-free or drift space between the bands 24 and 29, the energy of the electron stream may be utilized to maintain oscillations in the resonating system 10 and the system becomes a form of electronic oscillator.

To sustain oscillations, the electron group emerging from the drift space must arrive during a phase of the field such that the field opposes the motion of the electrons. Maximum energy transfer will occur when the electron group encounters an opposing field of maximum amplitude. Such a condition will occur when the transit time of the electron group in the drift space is equal to a quarter cycle of the resonant frequency of the system 10. Other favorable conditions for oscillations occur when the transit time in the drift space is equal to $(n + \frac{1}{4})$ cycles where n is any positive integer. The transit time is adjusted in known manner, as by varying the potential of the battery 14 or tuning the resonating system.

There is an advantage in employing a transit time of one quarter cycle inasmuch as this is the shortest transit time which will sustain oscillations. Difficulties are encountered in oscillating systems using drift spaces in which the transit time is equal to several cycles, due to the tendency

of the electrons to be dispersed by their mutual electrostatic repulsions. In practice the resonating system 10 may be located close to the cathode so that no focussing of the beam is required other than that afforded by the plates 19 or the amount of focussing provided in any ordinary type of electron gun. The collector 13 may be located relatively close to the resonating system 10 and the whole assembly including the envelope 11 thereby is rendered relatively short.

The output of the oscillator may be taken off through any suitable coupling system such as a coaxial transmission line as shown in Fig. 1 with outer conductor 40 and inner conductor 41, terminating in a loop 42 suitably placed inside the resonating system 10.

The arrangement lends itself well to the use of a tubular beam, although, of course, it may be used with electron streams of other types such as rays or sheets. It will be understood also that the use of electrons is merely illustrative and any other suitable electrically charged particles may be employed instead. Any suitable projector or gun may be employed for producing and projecting the stream of particles and any suitable arrangements may be provided for collecting and removing from the envelope the spent particles. The cross sectional shape of the resonator may also be varied within wide limits. If desired the resonating system need not extend to the central axis although the form shown with the central rods 34, 35 has the advantage of compactness.

What is claimed is:

1. An oscillating system comprising a source of a stream of electrically charged particles, a resonating chamber for electromagnetic waves, means to effect an energy interaction between the particles of said stream and an electromagnetic field in said resonating chamber, means within said resonating chamber to define for said stream a substantially field-free drift space, said drift space being of such a length that the said particles normally traverse it in a transit time of a value substantially an integral number of cycles of the resonant frequency of the chamber plus one quarter cycle, and means to predetermine a mode of oscillation of said resonating chamber characterized by equal potentials at the two ends of said drift space throughout the entire cycle of said resonating chamber.

2. An oscillating system comprising a source of a stream of electrically charged particles, a resonating chamber for electromagnetic waves, said chamber having arrangements accommodating the passage of the stream of particles from said source through a portion of the resonant cavity to interact with an electromagnetic wave therein, means within said resonating chamber defining for said stream a drift space shielded from said field, said drift space being of such length that the time of traverse by the charged particles is substantially one quarter cycle of the resonant frequency of said resonating chamber, and means for determining the mode of oscillation of said resonating chamber to be one adapted to maintain the two ends of the drift space at equal potentials throughout the entire cycle of said resonating chamber.

3. An oscillating system comprising means for maintaining a tubular beam of charged particles, a toroidal-shaped resonating chamber coaxial with said beam, said resonating chamber having an annular-shaped wall portion permeable to the charged particles of said beam and located in the path of said beam, and means within said reso-

5

nating chamber defining for said beam a substantially field-free drift space of a length substantially equal to the distance traversed by said charged particles in one quarter cycle of the resonant frequency of said resonating chamber, and means to predispose said resonating chamber to a mode of oscillation adapted to maintain the two ends of the drift space continuously in substantial phase agreement.

4. An oscillating system comprising means to maintain a tubular-shaped beam of electrons, a slotted, generally toroidal-shaped shell of conductive material having a U-shaped cross section and supported adjacent to and surrounding said electron beam, a pair of flanged circular conductive plates of slightly smaller diameter than said beam, said plates being supported coaxially with respect to the beam and substantially coplanar with the respective sides of the U-shaped shell, a pair of circular cylindrical conductive bands supported coaxially with respect to the beam and having slightly different diameters respectively, the outer of said bands having substantially the same diameter as the inner edge of the sides of said U-shaped shell and said inner band having substantially the same diameter as said circular plates, an axial conductor connecting the said circular plates, a plurality of radial conductors connecting said axial conductor to said inner conductive band, and a plurality of radial conductive rods connecting said U-shaped shell with said outer band, said conductive structure forming a chamber resonant at a given operating frequency, and said bands being of substantially equal width and said width being substantially equal to the distance traversed by the electrons of said beam during one quarter of a cycle of the said given operating frequency.

5. An oscillating system comprising a source of a stream of electrically charged particles, a resonating chamber for electromagnetic waves,

6

means to effect an energy interaction between the particles of said stream and an electromagnetic field in said resonating chamber, means within said resonating chamber to define for said stream a substantially field-free drift space, means to develop in the said stream an average velocity of the particles such that the particles traverse the said drift space in a transit time having substantially one of the values equal to an integral number of cycles including zero cycles of the resonant frequency of the said resonating chamber plus a quarter cycle, and means to predetermine the oscillations of said resonating chamber to follow a mode of oscillation characterized by equal instantaneous potentials at the two ends of said drift space throughout the entire cycle of oscillation.

6. An oscillating system comprising a source of a stream of electrically charged particles, a resonating chamber for electromagnetic waves, said chamber having a conductive inner surface, means to effect an energy interaction between the particles of said stream and an electromagnetic field in said resonating chamber, conductive means within said resonating chamber and spaced from the inner surface thereof to define for said stream a substantially field-free drift space, a conductive connection within said resonating chamber between said drift space defining means and the inner surface of said chamber, and means to develop in the said stream an average velocity of the particles such that the particles traverse said drift space in a transit time substantially equal to one of the values comprising an integral number of complete cycles, including zero, plus a quarter cycle, of the resonant frequency, of a mode of oscillation of the system comprising said resonating chamber, said drift space defining means and said conductive connection therebetween.

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