

Sept. 17, 1946.

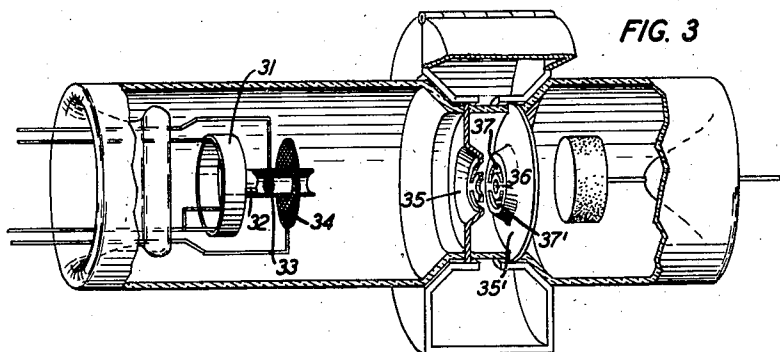
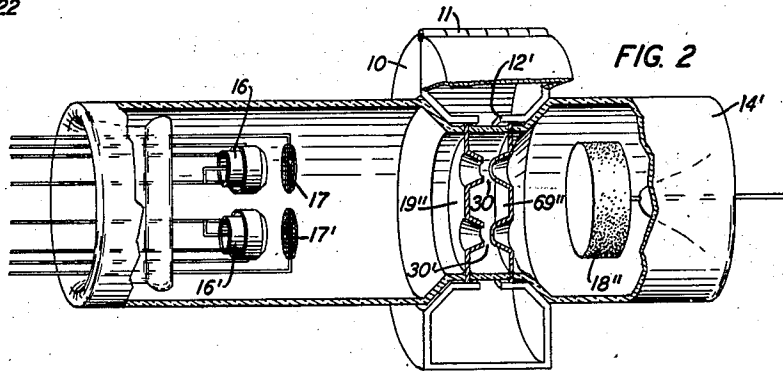
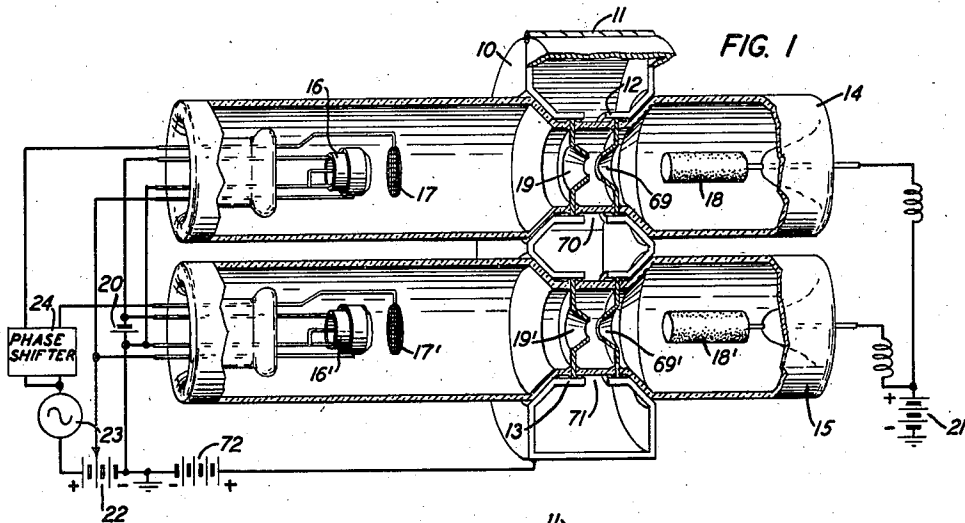
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2,407,667

HARMONIC GENERATOR

Filed Sept. 30, 1941

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

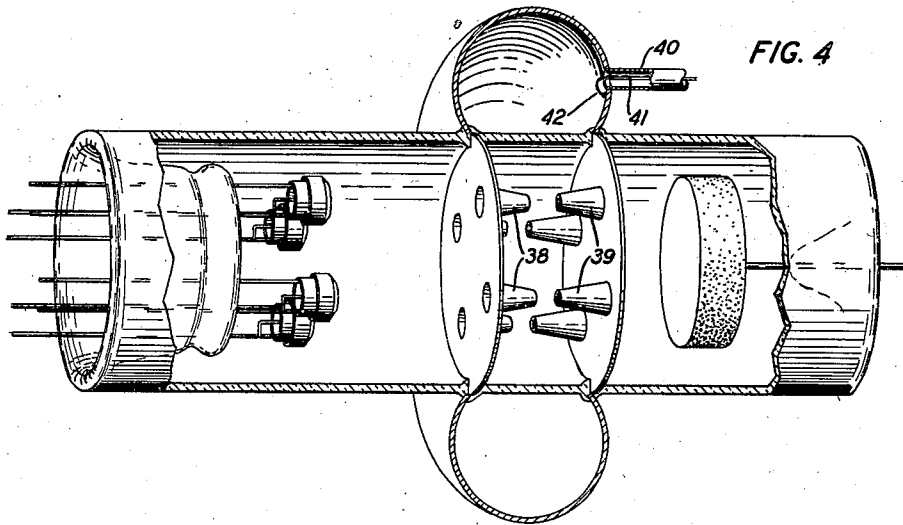


FIG. 4

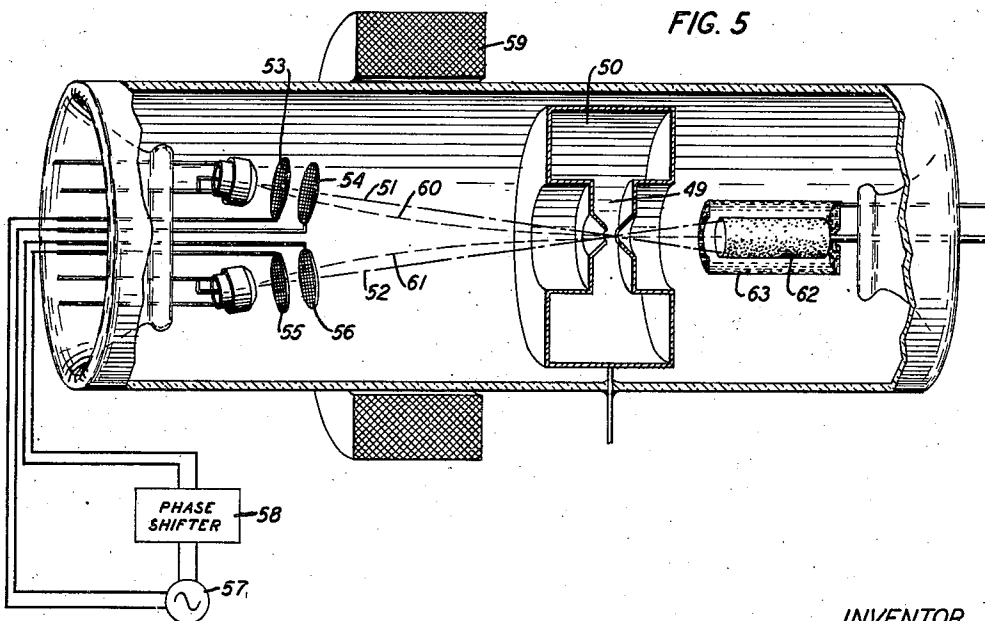


FIG. 5

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HARMONIC GENERATOR

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10 Claims. (Cl. 250—36)

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This invention relates to frequency doubling or multiplying arrangements and more particularly to systems for such purposes that employ energy reactions between streams of charged particles, e. g., electrons, and hollow electrical resonators.

In accordance with the invention two or more beams of charged particles are subjected to periodic density variations at a given fundamental frequency. This may be accomplished, for example, by first subjecting the beam to a periodic velocity variation, in which case means are provided to convert the respective velocity variations in each beam into corresponding electron density variations. The beams are then combined in such a way that their respective density variations are out of phase and so adjusted and interspersed as to constitute a succession of density variations occurring at a multiple of the fundamental frequency rate. The combined stream is employed to excite a resonator tuned to the harmonic frequency corresponding to the rate of density variations.

The invention is more fully described herein-after with reference to the accompanying drawings illustrating a number of embodiments, while the scope of the invention is defined in the appended claims.

In the drawings,

Fig. 1 shows an embodiment employing two electron beam tubes associated with a single electrical resonator;

Fig. 2 shows the use of two electron beams in a single envelope associated with a resonator;

Fig. 3 illustrates a concentric arrangement of electron beams in an embodiment otherwise similar to that shown in Fig. 2;

Fig. 4 illustrates the use of four electron beams in an arrangement embodying the invention; and

Fig. 5 shows the use of a pair of electron beams directed through a single gap in a resonator.

In Fig. 1 there is shown a hollow electrical resonator 10 which may consist of two similar halves connected by a hinge 11. The resonator may conveniently be in the form of a cylindrical can with a pair of eccentric interior cylindrical walls 12 and 13 which are formed to accommodate respectively a pair of vacuum tubes 14 and 15. The walls 12 and 13 are preferably each formed in half sections attached to the respective halves of the main body of resonator 10 so that when the resonator is opened by use of the hinge 11, the tubes 14 and 15 may readily be inserted.

The tube 14 contains a cathode 16, an electron permeable electrode or grid 17, an anode or col-

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lector 18 and a pair of apertured disc electrodes 19 and 69. The disc electrodes are preferably of conductive material fused to and extending through the insulating envelope of the tube. The protruding edges of the disc electrodes are preferably arranged to make a good electrical contact with the wall 12, on opposite sides of an annular slot 70 in the wall. The contact may be a frictional one maintained by the elasticity of the wall 12 or any other suitable arrangement may be used. The tube 15 contains parts 16', 17', 18', 19' and 69' corresponding respectively to 16, 17, 18, 19 and 69 in tube 14. The wall 13 is provided with a slot 71, which together with slot 70 interconnects the interior of the resonator 10 with the spaces between the disc electrodes for the free passage of electromagnetic waves to interact with the respective electron beams from the cathodes 16 and 16'.

Heating currents for the cathode heaters of the tubes are supplied from a battery 20 or other suitable source. The conductor system comprising the resonator 10 and the disc electrodes 19, 19', 69, 69' is connected to the positive terminal of a polarizing battery 72 or other suitable source. The collectors 18 and 18' are polarized, preferably at a somewhat lower positive potential, by a battery 21 or other suitable source, through high frequency choke coils, if desired. The electrodes 17 and 17' are polarized by means of a battery 22 or other suitable source connected to the electrodes by way of a source 23 of high frequency waves and a phase shifting device 24 of any known form.

In the operation of the system of Fig. 1, when the polarizing potentials and other auxiliary arrangements are properly adjusted, a wave, the frequency of which is to be modified, for example doubled, may be supplied by the source 23. By operation of the phase shifter 24 the wave from the source is impressed upon the respective electrodes 17 and 17' in unlike phases, for example 180 degrees out of phase in the case of frequency doubling. The electron streams from the respective cathodes 16 and 16' receive velocity variations due to the fluctuating potential on the respective electrodes 17 and 17'. In the space between the electrode 17 and the disc 19 a drift action occurs during which the accelerated electrons have an opportunity to overtake those electrons which have been slowed down, with the result that the electrons are formed into groups by the time they have reached the disc 19. The grouping of the electrons may be described as an electron density variation.

The passage of an electron concentration or electron group across the gap between the disc electrodes 19 and 69 induces a pulse of current on the inside of the walls of the resonator 10 and an accompanying electromagnetic wave in the interior space of the resonator in known manner. The passage of a succession of electron groups across the gap tends to maintain the space within the resonator in sustained electromagnetic oscillation, provided the resonant frequency of the resonator 10 is harmonically related to the frequency of the source 23. For example, the resonator 10 may be designed to resonate at twice the frequency of the source 23. The same effect is produced by the electron beam in the tube 15 but on account of the difference in phase, the alternations caused by the tube 15 are spaced in time between the alternations produced by the tube 14 so that the resonator 10 is excited at twice the fundamental frequency.

The cathodes 16 and 16' may each be accompanied by associated devices as known in the art for drawing electrons out of the cathode, and forming and focusing the electron beam. The separate sources 21, 22 and 72 may be replaced by a single source provided with taps at different potentials.

The tubes, resonator, coupling arrangements and mode of operation shown and described in connection with Fig. 1, with regard to details are intended as illustrative only and any other suitable arrangements may be used instead provided that a plurality of streams of charged particles have impressed upon them density variations at the fundamental frequency and that the streams are made to react in succession at proper intervals with the electric field in a suitable electrical resonator. In accordance with the invention the resonator may be maintained in oscillation at a harmonic of the impressed fundamental frequency by impressing electron density variations from a plurality of beams upon the resonator in succession, with proper phase relations between the density variations in the respective beams.

In the arrangement of Fig. 2 the hinged resonator 10 has a single internal wall 12' shaped to receive a single vacuum tube 14' containing cathodes 16 and 16', velocity varying electrodes 17 and 17', a single collector 18'' and disc electrodes 19'' and 69'' defining two eccentrically located gaps 30 and 30', each gap being aligned with one of the beam producing assemblies.

The arrangement shown in Fig. 2 may be employed in any suitable circuit, for example one generally similar to that shown in Fig. 1. The operation of the circuit is then substantially the same as that of the system of Fig. 1. The two electron streams alternately pass a group of electrons through one of the gaps 30 and 30' and in so doing alternately induce currents in the walls of the resonator 10 and maintain electromagnetic oscillations within the resonator. As in the case of the system of Fig. 1, when two beams are employed, and correctly phased, the frequency of the oscillations in the resonator 10 will be twice the frequency of the impressed waves.

Fig. 3 shows how a single cathode may be employed to produce two concentric beams of electrons which are made to react alternately with the associated resonator by passing the beams through concentric apertures in the coupling disc. The cathode is represented at 31 as having a relatively large circular emitting surface. A tube 32 of insulating material is employed to divide the

emission from the cathode 31 into two concentric beams, one inside and one outside the tube 32. A velocity varying electrode 33 for the inner beam is provided inside the tube 32 and an annular electrode 34 for the same purpose with respect to the outer beam is provided outside of the tube 32. Disc electrodes 35 and 35' are provided each with a central circular aperture 36 and two semi-circular annular apertures 37 and 37'.

The operation of the arrangement of Fig. 3 is similar to that described in connection with Figs. 1 and 2, the outer and inner beams being alternately effective in supplying an electron group which passes through one of the sets of apertures in the disc electrodes and induces a pulse of current in the resonator.

Fig. 4 shows the use of four electron beams in a single envelope. Each electron beam is passed through the interior of the resonating chamber by way of a pair of apertured conical electrodes 38, 39 and the beams may be excited in phase rotation so as to maintain the resonator in oscillation at a frequency four times that of the impressed waves. In connection with the arrangement of Fig. 4, a conventional output device for delivering energy at the harmonic frequency is shown, comprising a coaxial transmission line having an outer conductor 40 and an inner conductor 41, the latter terminating in an inductive loop 42 in the interior of the resonator.

Fig. 5 shows an arrangement wherein two electron beams are arranged to converge in a single gap 49 in a resonator 50. The resonator may be wholly enclosed within the vacuum tube envelope as shown in the figure, or it may be partly external and partly internal to the envelope, as desired. The paths of the respective beams are indicated by dot and dash lines 51 and 52, respectively. A pair of electron permeable electrodes 53, 54, are provided for impressing a velocity variation upon the beam 51 and a similar pair of electrodes 55, 56 are provided for velocity varying the beam 52. The source of fundamental frequency waves is indicated at 57 and is shown directly connected to the electrodes 53 and 54 and through a phase shifter 58 to the electrodes 55 and 56. As in the arrangement of Fig. 1, by so relating the phases of the density variations in the respective beams at the gap 49 by means of the phase shifter 58, the resonator 50 may be excited at a desired harmonic frequency. A magnetic focusing coil 59 may be employed if desired and may be so adjusted as to deflect the respective beams and bring them tangent to each other as they pass through the gap 49. The paths of the respective beams as modified by the coil 59 are shown in dotted lines 60 and 61. A collector 62 is provided and may be surrounded by a screen 63. The screen 63 may be provided with a large aperture to accommodate the divergent electron beams 51 and 52 and may be polarized to a somewhat more positive potential than the collector 62 in order to intercept and carry away any secondary electrons which may be emitted by the collector 62 under the impact of the beams.

When very high output frequencies are to be generated, the fundamental frequency impressed upon the velocity varying electrodes will itself be high and may be too high to allow the use of the simple input circuits shown in Figs. 1 and 5. In such cases, an input resonating chamber of known kind may be associated with a pair of electron permeable electrodes such as 53, 54 of Fig. 5 or in other words any of the known techniques for impressing ultra-high frequency velocity

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variations upon an electron beam may be employed. To secure the highest obtainable output frequencies, the fundamental frequency may be chosen at the upper limit of frequencies which can be generated directly, as for example, by means as an ultra-high frequency oscillator operating by virtue of velocity variation, and a very high multiple frequency may be derived therefrom by use of the apparatus and methods described herein.

In any of the systems described, the electron beams may be focused advantageously, using known means, either electrostatic or magnetic in nature, and the magnetic focusing fields may be produced either by permanent magnets or by electro-magnetic means.

Useful power at the final frequency may be withdrawn from any of the systems described by using an inductive loop and a connected coaxial transmission line as shown in Fig. 4 or by any other suitable means.

What is claimed is:

1. In a frequency changer, a source of waves of a given fundamental frequency, means to initiate and maintain a plurality of beams of charged particles, means for impressing density variations upon each of said beams in accordance with the fundamental waves in unlike phases, a resonator tuned to a multiple of the fundamental frequency, and means actuated in common by said beams to energize said resonator at the resonant frequency thereof.

2. In a frequency converting system a source of waves of a given fundamental frequency, means to initiate and maintain a plurality of beams of charged particles such as electrons, means for density varying each of said beams in accordance with the fundamental waves in unlike phases, a resonator tuned to a multiple of the frequency of said waves, means whereby said beams are caused to react successively upon said resonator to energize the same at its resonant frequency, and means for extracting energy from said resonator at said resonant frequency.

3. In a frequency converter, a source of waves of a given fundamental frequency, a pair of electron beam devices, means for velocity varying said beams in accordance with the fundamental waves in opposite phases, means associated with each beam to convert the velocity variations to corresponding density variations, a resonator tuned to twice the fundamental frequency, and means actuated jointly by both beams to energize said resonator at twice the fundamental frequency.

4. In a frequency changer, a source of waves of a given fundamental frequency, an evacuated envelope, means contained within said envelope for projecting a plurality of beams of charged particles, means for density varying each of said beams in accordance with the fundamental waves in unlike phases, a resonator tuned to a multiple of said fundamental frequency, means contained within said envelope and actuated in common by said plurality of beams to energize said resonator at the resonant frequency, and a load circuit coupled to said resonator.

5. In a frequency changing system, an evacuated envelope, means contained within said envelope to project a plurality of streams of electrons, said streams being concentrically and coaxially arranged with respect to each other, insulating

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means separating the said individual streams of electrons, means individual to each stream for density varying the electrons of said stream in accordance with a fundamental impressed wave in unlike phases, a resonator tuned to a multiple of said fundamental frequency corresponding to the number of said streams of electrons, and means actuated in common by said plurality of streams to energize said resonator at its resonant frequency.

6. In combination, a source of waves of fundamental frequency, a hollow resonating body tuned to a harmonic of said fundamental frequency, a plurality of means for initiating and maintaining distinct electron streams, a plurality of means for coupling between an electron stream and an electromagnetic field within said hollow resonant body, each of said coupling means serving to couple one of said electron streams to said electromagnetic field, means to displace the relative phases of fundamental wave frequency effects in the respective electron streams whereby said hollow resonating body is energized at said harmonic frequency by said electron streams successively, and means for extracting energy from said hollow resonating body at said harmonic frequency.

7. In a harmonic generating system, a hollow resonating body, means defining a plurality of electron permeable gaps within said body, means for initiating and maintaining a plurality of electron beams, one of said beams passing through each of said gaps, a source of waves of fundamental frequency, means for varying a characteristic property of each of said beams at a rate corresponding to the frequency of said fundamental waves, and means for causing said electron beams in rotation to react successively in said gaps to energize said hollow resonant body at said harmonic frequency.

8. In a harmonic generating system, a source of waves of fundamental frequency, a hollow resonant body tuned to a harmonic of said fundamental frequency, means for defining an electron permeable gap in said resonating body, means for initiating and maintaining a plurality of streams of charged particles and directing a plurality of said streams through said gap, individual means for density varying said streams in accordance with said waves of fundamental frequency, and means for shifting the relative phases of the respective density variations of said streams whereby said hollow resonating body is energized by the combined successive density variations of said streams passing through said gap.

9. In combination with the arrangement of claim 8, means for deflecting said streams to render the paths of a plurality of said streams substantially colinear through said gap.

10. In a frequency multiplying system, means to initiate and maintain a plurality of beams of charged particles, means for impressing charge density variations upon each of said beams in synchronism with a given wave the frequency of which is to be multiplied, means for displacing the relative phases of the said charge density variations as between the respective beams, a resonator tuned to a multiple of the given frequency, and means actuated successively by said beams to energize said resonator at the resonant frequency thereof.

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