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F. LÜDI

2,364,732

ULTRA HIGH FREQUENCY GENERATOR

Original Filed March 6, 1941

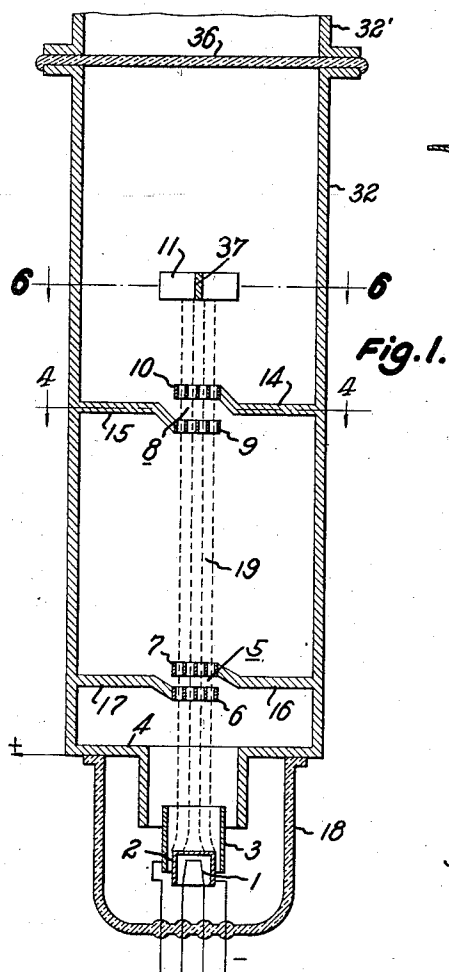


Fig. 1.

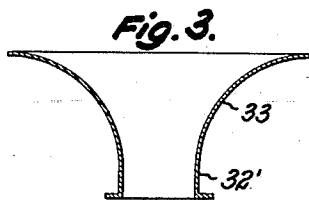


Fig. 3.

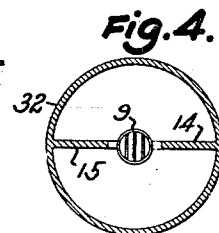


Fig. 4.

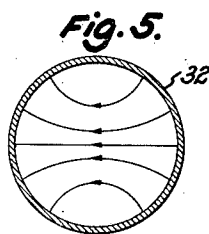


Fig. 5.

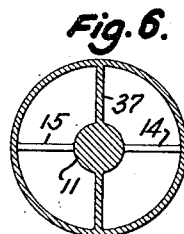


Fig. 6.

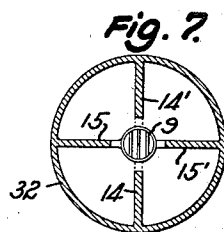


Fig. 7.

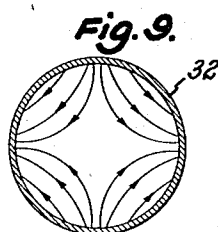


Fig. 9.

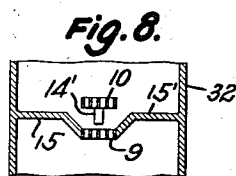


Fig. 8.

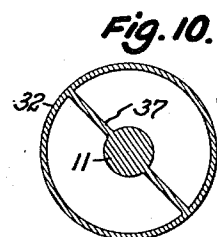


Fig. 10.

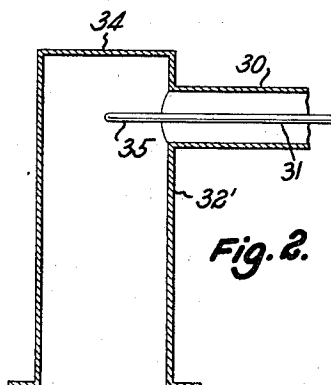


Fig. 2.

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2,364,732

ULTRA HIGH FREQUENCY GENERATOR

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Original application March 6, 1941, Serial No. 382,089, now Patent No. 2,323,613, dated July 6, 1943. Divided and this application October 8, 1942, Serial No. 461,321. In Switzerland February 28, 1940

12 Claims. (Cl. 315-5)

With ultra short wave generators operating according to the principle of phase focussing, in order to produce ultra high frequency oscillations a velocity variation in accordance with an ultra high frequency period is impressed in a modulator on an electron beam having an initial homogenous velocity. As a result of this velocity variation more or less definite groups of electrons are formed at a certain distance beyond the modulator, these electrons producing alternating voltages of ultra high frequency in a so-called inductor. The self-excitation of such a generator is brought about by means of a feed-back arrangement whereby the voltages occurring in the inductor are fed back to the modulator.

A particularly favourable feed-back arrangement is known, which only requires a single resonator which is connected to the inductor and modulator in such a manner that the amplitude of the ultra high frequency voltages is smaller at the modulator than at the inductor, an ultra high frequency load being coupled to the resonator providing the feed-back.

The present invention concerns an ultra short wave generator, in which the resonator which acts as the feed-back between the inductor and the modulator consists of a tubular wave conductor one end of which at least is closed electrically, the inductor and modulator being arranged in such a manner inside the hollow space of the conductor and being provided with antennae so that the coupling between them is brought about by the ultra high frequency waves occurring in the hollow space inside the conductor. Compared with arrangements using Lecher systems and concentric tubular conductors, a wave conductor which is closed electrically at one end offers considerable advantages when employed for tubes with phase focussing. The oscillations thus produced can then be passed directly through the wave conductor or be radiated into space. The assembly of a phase-focussing generator employing a wave conductor as a resonator is very simple and possesses the advantage that all highly stressed electrodes can be cooled directly. Furthermore with very short waves it is especially favourable when the natural frequency of such a resonator is mainly determined by the bore of the conductor tube and not by the axial length as is the case with a Lecher system or a concentric pipe, whilst the axial length can be made as long as is desired.

This modified form of the invention is illustrated diagrammatically by means of the con-

structional examples shown in Figs. 1 to 10 of the accompanying drawing.

In the drawing,

Fig. 1 is a longitudinal section through a generator embodying the principles of the invention;

Fig. 2 is a partial representation in section of a fitting to connect the generator with a load;

Fig. 3 is a sectional representation of a fitting for the radiation of oscillations from the generator;

Fig. 4 is a transverse section on line 4-4 of Fig. 1;

Fig. 5 is a diagrammatic representation of the electrical field distribution obtained with the inductor antennae of Fig. 4;

Fig. 6 is a transverse section on line 6-6 of Fig. 1;

Fig. 7 is a transverse section, and Fig. 8 is a longitudinal section, showing a modification of the arrangement of the inductor antennae;

Fig. 9 is a diagrammatic representation of the electrical field distribution obtained with the inductor antennae of Figs. 7 and 8, and

Fig. 10 is a transverse section showing the preferred arrangement of the anode supports used in connection with the inductor antennae of Figs. 7 and 8.

According to the longitudinal section shown in Fig. 1 the resonator forming the feed-back between the inductor 8 and the modulator 5 consists of a wave conducting tube 32 which is closed electrically at one end by the metal wall 4 and inside of which the inductor electrodes 9, 10 and the modulator electrodes 6, 7 are provided with antennae 14, 15, 16, 17 in such a manner that the coupling between the modulator and inductor is achieved by means of the ultra high frequency waves generated in the hollow space of the wave conductor. These antennae are fixed inside the wave conducting tube and serve at the same time as supports for the inductor and modulator electrodes. Inductor 8, modulator 5 and anode 11 are preferably not located in an insulator housing inside the wave conductor 32 which would limit the vacuum space of the generator, but to avoid undesirable reflections at such insulator elements are supported freely inside the wave conductor as shown in Figs. 4 and 6 which depict cross-sections on the lines 4-4 and 6-6 respectively in Fig. 1. The entire hollow space inside the conductor 32, at least between the modulator, inductor and anode thus also belongs to the vacuum space of the generator. At the modulator end the conductor tube 32 is terminated by a metal

cover plate 4 which possesses a central aperture through which the electron beam enters. If desired a coarse mesh grid electrode can be located in this aperture. This aperture is covered by a tube head-piece 18 of insulating material in which the filament 1, cathode 2, Wehnelt cylinder 3 and any other additional electrodes for forming and accelerating the electron beam, together with the current leads, are located. The cylindrical extension of the cover plate 4 shown in the drawing can serve as an accelerating electrode if the positive pole of a high voltage direct current supply is connected to the metallic conductor tube.

To enable the wave conductor tube 32 to be coupled to an ultra high frequency load it is provided with an extension beyond the anode 11. If the oscillations are to be radiated directly into space the wave conductor tube 32 can be provided with a funnel-shaped end piece 33 as shown in Fig. 3, this end piece being so dimensioned that the wave resistance of the free space is adjusted in the best possible manner to suit the generator. If, on the other hand, the ultra high frequency load is located some distance away from the generator and if the high frequency energy produced is to be used in the form of electric alternating currents which circulate in wire conductors, it is expedient to equip the extension 32' of the conductor tube with a metallic cover plate 34 as indicated in Fig. 2 and an antenna 35, which for coupling the load circuit extends into the tube 32' and supplies a power conductor, for instance a concentric tubular conductor 30, 31, which is connected to the load. With the constructional form illustrated in Fig. 2 care must be taken that the distance of the cover plate 34 from the cover plate 4 at the modulator end of the tube is an even multiple of twice the distance between the inductor 8 and the cover plate 34, so that in wave conductors which are thus closed at both ends standing waves are excited and the inductor is located at the point where the electrical fields are a maximum. Under these conditions the modulator 5 will thus receive ultra high frequency voltages whose amplitude corresponding to their distance from the cover plate 4 is smaller than the amplitudes prevailing at the inductor electrodes. If, however, the wave conductor 32 shown in Fig. 1 is equipped with a funnel 33 (Fig. 3) then, on condition that the funnel is correctly adjusted, there will only be a standing wave between the cover plate 4 and the inductor 8, whilst beyond the inductor 8 there will only be a progressing wave which is radiated by the funnel without reflection.

The funnel-shaped end piece shown in Fig. 3 or the cover plate in Fig. 2, both of which must have the same diameter at the lower flange ends of extension 32' as the wave conductor tube 32 in Fig. 1, can be connected galvanically and vacuum-tight to the tube 32. In order to limit the vacuum space an insulating piece must then, however, be provided for the arrangement shown in Fig. 2, between the inner conductor 31 and the outer tube 30, this insulating piece acting as a vacuum-tight closing piece for that part of the extension 32' which contains the antenna. If the wave conductor 32 is joined directly to the funnel 33 shown in Fig. 3, then the funnel entrance should for instance be closed in a vacuum-tight manner with insulating material in order to limit the vacuum space. To enable the generator to be universally used it is, however, pref-

erable to shut off the vacuum space of the generator as shown in Fig. 1 by means of a special wall 36 of insulating material which should expediently consist of ceramic material with small dielectric losses, whilst on the other side of this wall the tube conductor is provided with an extension into the atmosphere as indicated by the member 32'. The extension 32' can then also be fitted with a funnel as shown in Fig. 3 or an electrical cover plate as indicated in Fig. 2. The distance between the insulating wall 36 and the cover plate 4 is then also selected to be equal to a whole number multiple of twice the distance between the inductor and the cover plate 4, so that the reflected waves due to the electrical losses in the insulating wall 36 are in phase with the standing waves between the inductor and cover plate 4.

By employing a wave conductor which is at least shut off at one end as a resonator for determining the frequency, very considerable advantages can be obtained as regards ultra short waves for generators operating with phase focusing. The natural frequency is namely mainly fixed by the size of the tube section and the form of excitation so that the tube length can be selected as desired. The distance between the cover plate 4 and the inductor 8 can thus be a multiple of the wave length generated in the free space, so that the geometric dimensions of the generator never become abnormally small even for the shortest waves in the centimetre range, such as would be the case if a Lecher system or concentric tubular conductors were used. Although the electron beam 19 moves forward through the hollow space in the wave conductor it is possible by means of a special excitation to prevent any axial velocity variation of the electron beam in the direction of its expansion which might be caused by the electric field in the wave conductor. This is achieved by exciting the wave conductor in so-called H-waves which only possess a magnetic but not an electrical alternating field in the axial direction. For the excitation of H-waves the antenna 14, 15 connected to the inductor electrodes 9, 10 must be located in the same plane perpendicular to the axis of the wave conductor.

With the inductor antenna arranged as shown in Fig. 1 of which a cross-section is shown in Fig. 4, so-called H₁-waves are formed whose path in the tube 32 is indicated in Fig. 5. The arrows in Fig. 5 reverse their direction after each half period of the alternating field. A comparison of Figs. 4 and 5 shows that the electrical field is mainly perpendicular to the direction of the inductor antenna. To prevent the leads 37 to the anode 11 in Fig. 6 from disturbing the electrical field, these must be located perpendicular to the latter. For the H₁-waves the anode 11 including the leads 37, which at the same time serve to fix the former, must be arranged as shown in Fig. 6. With H₁-waves it is also unfavourable that the electrical field (Fig. 5) is strongest in the vicinity of the axis of the wave conductor because the electron beam is subjected to detrimental transverse deflections having an ultra high frequency. Such transverse deflections can be avoided by the excitation of an H-wave of a higher order whereby it is possible, according to the excitation selected, to obtain in the vicinity of the axis a space which is practically free from electrical lines of force. The excitation of an H₂-wave in a wave conductor with annular cross-section is particularly favourable.

For this purpose the inductor electrodes 9 and 10 are provided with antennae 14 and 15 which are located at 90° to each other as shown in Figs. 7 and 8, it being of no importance if the inductor electrode 9 is only connected to the antenna 15 or to both antennae 15 and 15'. On condition that the antennae for both inductor electrodes have the same form, for instance double antennae for each electrode as shown in the figure, an electrical field distribution as indicated in Fig. 9 will be obtained, so that there are practically no electrical lines of force at the axis and therefore no disturbing influence on the electron beam. In accordance with the field distribution shown in Fig. 9 the anode supports 37 are located as indicated in Fig. 10 so that the anode 11 and the supports 37 do not disturb the electrical field. Excitations of a higher order than the second are very rarely an advantage and only then when it is a question of generating extremely short waves. An excitation of the second order as described above is adequate in every respect for obtaining a space at the axis which is not subject to an electrical field. Instead of wave conductors with an annular cross-section it is also possible for instance to employ conductors with a rectangular cross-section, without in any way affecting the fundamental properties of the generator. It is preferable if the modulator antennae are of the same construction as the inductor antennae and are arranged parallel to the latter. The antennae of the inductor and modulator and also the anode supports 37 (Figs. 6 and 10) can also serve as supply and discharge conduits for a liquid cooling medium which is used to carry away the power losses at the inductor and modulator electrodes and also at the anode. In order to cool these parts it is often sufficient if only the wave conductor tube 32 in Fig. 1 is cooled by a liquid cooling medium.

This application is a division of my application Serial No. 382,089, filed March 6, 1941 now U. S. Patent No. 2,323,613.

I claim:

1. An ultra short wave generator comprising means for generating an electron beam in an evacuated space, a modulator comprising a pair of grid electrodes positioned in the path of said beam for subjecting the beam to ultra high frequency potential variations whereby ultra high frequency velocity variations are produced in the beam, an inductor comprising a pair of grid electrodes positioned in the path of the modulated beam whereby ultra high frequency alternating voltages are produced in said inductor, and a feed-back connection between said modulator and said inductor comprising a single resonator to which the ultra high frequency load is to be connected, said resonator comprising a wave conductor tube which is electrically closed at one end, the inductor and the modulator being positioned within said tube and provided with antennae whereby the coupling between the inductor and the modulator is effected by the ultra high frequency waves within said tube.

2. An ultra short wave generator comprising means for generating an electron beam in an evacuated space, a modulator comprising a pair of grid electrodes positioned in the path of said beam for subjecting the beam to ultra high frequency potential variations whereby ultra high frequency velocity variations are produced in the beam, an inductor comprising a pair of grid electrodes positioned in the path of the modulated beam whereby ultra high frequency alternating

voltages are produced in said inductor, and a feed-back connection between said modulator and said inductor comprising a single resonator to which the ultra high frequency load is to be connected, said resonator comprising a wave conductor tube which is electrically closed at one end, the inductor and the modulator being positioned within said tube and provided with antennae whereby the coupling between the inductor and the modulator is effected by the ultra high frequency waves within said tube, said antennae also supporting the inductor and the modulator from said tube.

3. An ultra short wave generator comprising means for generating an electron beam in an evacuated space, a modulator comprising a pair of grid electrodes positioned in the path of said beam for subjecting the beam to ultra high frequency potential variations whereby ultra high frequency velocity variations are produced in the beam, an inductor comprising a pair of grid electrodes positioned in the path of the modulated beam whereby ultra high frequency alternating voltages are produced in said inductor, and a feed-back connection between said modulator and said inductor comprising a single resonator to which the ultra high frequency load is to be connected, said resonator comprising a wave conductor tube which is electrically closed at one end, the inductor and the modulator being positioned within said tube and provided with antennae whereby the coupling between the inductor and the modulator is effected by the ultra high frequency waves within said tube, the wave conductor tube at the modulator end thereof being provided with a metallic cover plate having a central aperture and a head piece of insulating material carrying the current leads to the electron beam generating means.

4. An ultra short wave generator as defined in claim 3 in which the wave conductor tube is closed at the end opposite from the modulator at a distance from said metallic cover plate which is a whole number multiple of twice the distance between the modulator and said cover plate.

5. An ultra short wave generator as defined in claim 3 in which the wave conductor tube is closed by an insulating cover plate at the end opposite from the modulator at a distance from said metallic cover plate which is a whole number multiple of twice the distance between the modulator and said cover plate and an extension of said tube beyond said insulating cover plate.

6. An ultra short wave generator as defined in claim 3 in which the wave conductor tube is closed by an insulating cover plate at the end opposite from the modulator at a distance from said metallic cover plate which is a whole number multiple of twice the distance between the modulator and said cover plate and an extension of said tube beyond said insulating cover plate, a funnel-shaped end piece being provided in said extension whereby the ultra high frequency oscillations are radiated into free space.

7. An ultra short wave generator as defined in claim 3 in which the wave conductor tube is closed by an insulating cover plate at the end opposite from the modulator at a distance from said metallic cover plate which is a whole number multiple of twice the distance between the modulator and said cover plate and an extension of said tube beyond said insulating cover plate including a metallic cover plate for the extension and an antenna projecting into the ex-

tension and connected to a conductor leading to the ultra high frequency load.

8. An ultra short wave generator comprising means for generating an electron beam in an evacuated space, a modulator comprising a pair of grid electrodes positioned in the path of said beam for subjecting the beam to ultra high frequency potential variations whereby ultra high frequency velocity variations are produced in the beam, an inductor comprising a pair of grid electrodes positioned in the path of the modulated beam whereby ultra high frequency alternating voltages are produced in said inductor, and a feed-back connection between said modulator and said inductor comprising a single resonator to which the ultra high frequency load is to be connected, said resonator comprising a wave conductor tube which is electrically closed at one end, the inductor and the modulator being positioned within said tube and provided with antennae whereby the coupling between the inductor and the modulator is effected by the ultra high frequency waves within said tube, the antennae connected to the inductor being located in a plane perpendicular to the axis of the tube whereby H-waves possessing magnetic but no electrical components in the axial direction of the tube are excited.

9. An ultra short wave generator comprising means for generating an electron beam in an evacuated space, a modulator comprising a pair of grid electrodes positioned in the path of said beam for subjecting the beam to ultra high frequency potential variations whereby ultra high frequency velocity variations are produced in the beam, an inductor comprising a pair of grid electrodes positioned in the path of the modulated beam whereby ultra high frequency alternating voltages are produced in said inductor, and a feed-back connection between said modulator and said inductor comprising a single resonator to which the ultra high frequency load is to be connected, said resonator comprising a wave conductor tube which is electrically closed at one end, the inductor and the modulator being positioned within said tube and

provided with antennae whereby the coupling between the inductor and the modulator is effected by the ultra high frequency waves within said tube, the antennae connected to the inductor being located in a plane perpendicular to the axis of the tube and positioned angularly with respect to each other whereby H-waves of an order higher than 1 having only weak electrical forces in the vicinity of the tube axis are excited.

10. An ultra short wave generator comprising means for generating an electron beam in an evacuated space, a modulator comprising a pair of grid electrodes positioned in the path of said beam for subjecting the beam to ultra high frequency potential variations whereby ultra high frequency velocity variations are produced in the beam, an inductor comprising a pair of grid electrodes positioned in the path of the modulated beam whereby ultra high frequency alternating voltages are produced in said inductor, and a feed-back connection between said modulator and said inductor comprising a single resonator to which the ultra high frequency load is to be connected, said resonator comprising a wave conductor tube which is electrically closed at one end, the inductor and the modulator being positioned within said tube and provided with antennae whereby the coupling between the inductor and the modulator is effected by the ultra high frequency waves within said tube, the antennae connected to the inductor being located in a plane perpendicular to the axis of the tube and positioned at 90° with respect to each other whereby H₂-waves having only weak electrical forces in the vicinity of the tube axis are excited.

11. An ultra short wave generator as defined in claim 8 wherein the anode is attached to the wave conductor tube by means of supporting members positioned in a plane perpendicular to the tube axis and at right angles to the electric lines of force of the H-waves.

12. An ultra short wave generator as defined in claim 8 wherein the antennae connected to the modulator are parallel to the antennae connected to the inductor.

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