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H. J. VON BAEYER

2,579,630

MICROWAVE GENERATOR

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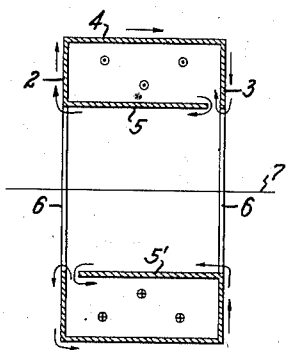


Fig. 1.

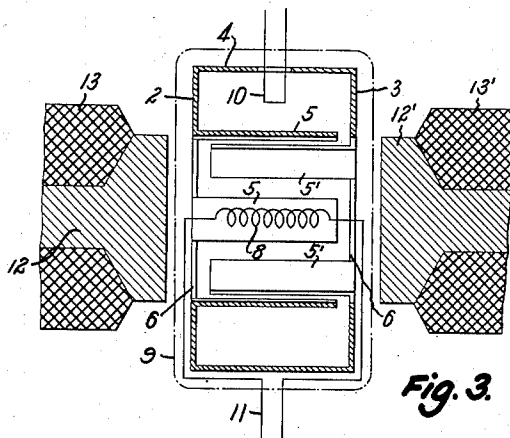


Fig. 3.

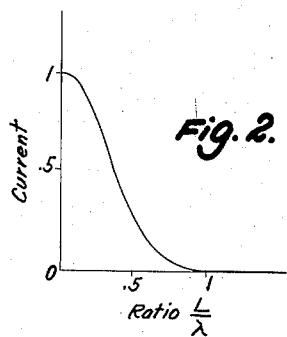


Fig. 2.

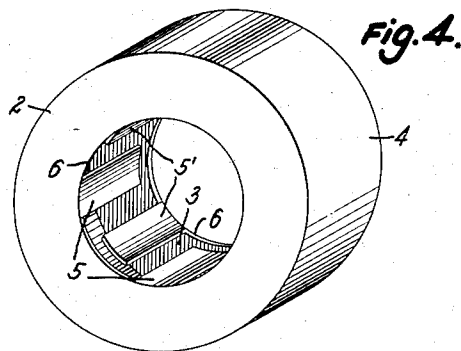


Fig. 4.

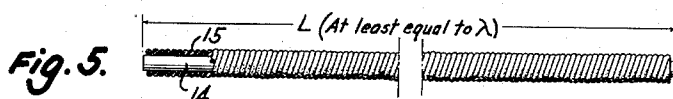


Fig. 5.

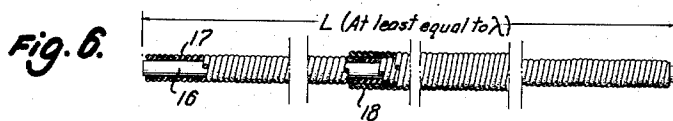


Fig. 6.

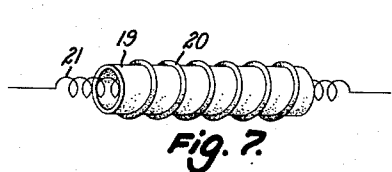


Fig. 7.

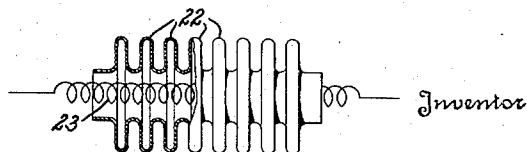


Fig. 8.

Hans Jacob Von Baeyer
By Pierce Scheffler & Parker
Attorneys

UNITED STATES PATENT OFFICE

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MICROWAVE GENERATOR

Hans Jakob von Baeyer, Baden, Switzerland, assignor to "Patelhold" Patentverwertungs- & Elektro-Holding A.-G., Glarus, Switzerland

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6 Claims. (Cl. 315—39)

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This invention relates generally to devices for generating ultra-high frequency electrical oscillations, i. e. in the centimeter range, and more particularly to those of the type in which electrons emitted radially from an elongated cathode transfer energy to an annular hollow resonator arranged concentric about the axis of the cathode. The resonator has annular end walls and is bounded in a radial direction by outer and inner cylindrical walls, the inner wall being constituted by a cylindrical array of spaced anode segments, adjacent segments in the array being secured to opposite end walls of the resonator such that alternating potentials are developed between adjacent segments as the resonator oscillates. Through the combined actions of a constant radial electric field established between the cathode and the array of anode segments by an applied potential and a unidirectional magnetic field established axially, the electrons leaving the cathode are caused to travel in cycloidal paths and form into bundles which then give up energy, originating from the constant electric field, to the alternating field of the cavity resonator to maintain the latter in a state of oscillation at a constant frequency which is determined solely by its dimensions and the capacity between the anode segments. This general type of generator is described in further detail in a co-pending United States application of Fritz Ludi, Ser. No. 478,533, filed March 9, 1943, and also in an article prepared by him which appeared in *Helv. Phys., Acta*, vol. XIII fasc. Sext (1940).

While this type of micro-wave generator has been found to produce generally satisfactory results, the structural designs developed in the past have had one rather serious operating disadvantage which stems from the heretofore unavoidable coupling between the high frequency magnetic field within the resonator chamber and the cathode which it encloses.

The general object of this invention is to provide an improved generator of the class described in which the coupling between the resonator field and the cathode is eliminated altogether, and the objective is attained by making the length of the cathode enclosed by the high frequency field at least equal to the wave length λ of the lowest, i. e., the basic, frequency produced by the generator. By "at least equal to" I mean that the cathode cannot be shorter than the wavelength λ but it can however be made longer than λ if desired.

Several practical arrangements for a cathode

having the required dimensional characteristics have been included in the accompanying drawings. Fig. 1 is a view in axial section of a resonator which has been included to illustrate the nature of the undesirable operating characteristic eliminated by this invention; Fig. 2 is a curve used in conjunction with the explanation of Fig. 1; Fig. 3 is an axial section showing a typical structural arrangement of a high frequency generator to which the invention in one form has been applied; Fig. 4 is a perspective view of the hollow resonator shown in section in Fig. 3; and Figs. 5-8 are views illustrating modified structural arrangements for a cathode embodying the invention which may be substituted for the cathode structure illustrated in Fig. 3.

To better understand the nature of the present invention, it will be well to first consider Figs. 1 and 2 of the drawing. The resonator as previously explained has annular end walls 2 and 3 of conductive material, an outer conductive cylindrical wall 4 and an inner wall constituted by a cylindrical array of equally spaced and paired conductive anode segments 5, 5', adjacent segments in the array terminating in alternation on opposite end walls. That is to say, segments 5 extend axially from end wall 2 to a point just short of end wall 3 and segments 5' interleaved with segments 5 extend axially from end wall 3 to a point just short of end wall 2. This arrangement for an eight segment resonator, i. e., four pairs of segments 5, 5' is more clearly shown in Fig. 4. The course of the high frequency magnetic field within the resonator, neglecting minor stray fields in the immediate vicinity of the central openings 6 in end walls 2, 3 through which are passed the leads for the cathode the axis of which is, indicated generally at 7, is indicated by the usual symbols $\oplus$ and $\odot$. Ideally, this high frequency field should be free from any extraneous disturbing effects, but prior to this invention such has not been the case because of the heretofore unavoidable coupling between the field and the cathode system. Briefly, a current induced by the high frequency magnetic field can flow on the cathode into the resonator chamber on the one hand, and out of the same on the other; on the basis of field equalization, a current must also flow on the outer skin of the resonator surrounding the cathode, the directional characteristics of the latter current being indicated by the arrows in Fig. 1. It is through this current on the outer skin that disturbing extraneous fields and charges have heretofore been able to be coupled inside the cavity.

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I have found that these harmful disturbances can be eliminated altogether by making the length of the cathode enclosed by the high frequency field at least equal to the wave length λ of the lowest i. e. basic frequency produced by the generator, the effect of which is to eliminate all induction of high frequency currents in the cathode circuit. A mathematical presentation of the theory involved is not considered necessary to a complete understanding of the invention and hence has been deleted in the interest of simplifying the disclosure. Briefly, however, mathematical analysis shows that the amplitude of the harmful high frequency current, induced in the cathode, decreases as the ratio of the length L of the cathode to the wavelength λ of the basic high frequency field produced within the resonator, i. e. L/λ approaches unity, and becomes substantially zero, in fact less than 1% of the maximum theoretically obtainable, when and after unity is reached. The curve in Fig. 2 in which the amplitude of the induced current is plotted against the ratio L/λ shows the character of the decrease in current with an increase in the ratio L/λ .

As previously explained, several practical constructions for the cathodes are possible. Referring now to Figs. 3 and 4, it will be observed that the resonator is basically the same as that which has already been described in connection with Fig. 1. The cathode element is located along the axis of the resonator and in accordance with the invention that portion of the cathode enclosed by the high frequency field, i. e. the portion lying between end walls 2 and 3, is given a length at least equal to the wave length λ of the basic frequency of the field produced within the resonator. Here the cathode 8 is shown to be of the directly heated type consisting of a helical coil of wire disposed between the end walls 2, 3 having a good electron emissive characteristic such as thoriated tungsten and its length before being helically coiled is at least equal to the aforesaid wave length λ .

In the general type of high frequency generator under consideration, the dimension of the resonator as measured along the cathode axis has an upper limit of one-fourth of the wave length λ of the fundamental frequency and in many designs thus far considered, this dimension has been of the order of only one-tenth the wave length. Hence in order to obtain the necessary length of cathode, helical coiling of the same appears to be the most practical.

The resonator and cathode structures are enclosed within an evacuated envelope 9, a coupling loop 10 within the resonator is used for the extraction of high frequency energy, cathode 8 is heated by application of current from a suitable source, not illustrated, to input leads 11, and the necessary unidirectional magnetic field in which the lines of force extend parallel with the cathode is established between pole pieces 12, 12' of a generally C-shaped electro-magnetic structure located exteriorly of envelope 9, the magnet being provided with coils 13, 13' that are energized from a source of direct current.

A modified form of directly heated cathode is illustrated in Fig. 5. The cathode is comprised of a tungsten wire 14 which prior to being formed into a helix is wound tightly with a winding of nickel alloy wire 15 that is coated with any of the oxides known to have a high electron emissive characteristic, it being understood of course that the length of the cathode wire before form-

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ing the helix is at least equal to the wavelength λ as before.

Fig. 6 shows a modification of the general arrangement illustrated in Fig. 5 for preventing the cathode from overheating and is especially suited in applications where the center portion of the cathode tends to heat up more than the end portions. Here it is seen that the entire length of the tungsten wire 16, at least equal to the wave length λ , is surrounded by a tightly wound layer of oxide-coated nickel alloy wire 17, the same as in Fig. 5, but at the center section of the cathode, it will be observed that one or more additional layers 18 of the nickel alloy wire are superimposed upon layer 17 to thereby provide a larger mass of material at the center section for more rapidly dissipating the higher heat existing in this zone. Another practical arrangement for increasing the rate of heat dissipation from the center section of the cathode would be to wind the nickel alloy wire on to the tungsten wire with a varying pitch, the minimum pitch being located at the center section of the wire to thereby provide a larger mass in this zone.

Figure 7 illustrates an application of the present invention to a cathode of the indirectly heated type. Here the cathode is seen to be comprised of a cylindrical ceramic tube 19 upon which a nickel alloy wire 20 coated with an electron emissive oxide is wound in the form of a helix. A tungsten coil 21 extending through tube 19 constitutes the heater element, and the length of both windings 20 and 21, in their uncoiled states, must be at least equal to the wavelength λ of the basic frequency of the resonator.

Figure 8 shows another practical cathode structure of the indirectly heated type according to the invention. The cathode in this view is comprised of a hollow cylinder of metallic sheet material, preferably molybdenum, folded to form a bellows 22, within which is placed a helically wound heater coil 23 of tungsten wire. However, since both the bellows cathode 22 and the heater coil 23 must have a length at least equal to the wavelength λ as in the other forms of the invention and it may prove technically difficult to get the required length in the axial space between the end walls 2, 3 of the resonator, this form of cathode will be most practical for generators of such design that the distance between the resonator end walls 2, 3 is equal or nearly equal to the upper limit of one-quarter of the wavelength λ of the high frequency oscillations produced by the generator.

In conclusion, I wish it to be understood that while the drawings illustrate several different forms of cathode structures suitable for use in high frequency generators of the class described to obtain the desired result, yet other structural arrangements may be devised without departing from the spirit and scope of the inventive concept as expressed in the foregoing disclosure and defined in the appended claims.

I claim:

1. A high frequency generator comprising a cathode, an annular resonator surrounding said cathode coaxially, said resonator including spaced end walls and bounded in a radial direction by an outer cylindrical wall and an inner wall constituted by a cylindrical array of inter-fitting anode segments terminating in alternation on said end walls, and means located outside said resonator and so oriented as to produce a unidirectional magnetic field parallel to the cathode axis within the space defined by said

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anode segments, length of said cathode between said end walls being at least equal to the wavelength of the basic frequency produced by the generator.

2. A high frequency generator as defined in claim 1 wherein said cathode is of the directly heated type constituted by a helical electron emissive coil.

3. A high frequency generator as defined in claim 1 wherein said cathode is comprised of a helical coil adapted to be directly heated and upon which is wound a coil of wire having a layer of electron emissive material thereon.

4. A high frequency generator as defined in claim 1 wherein said cathode is comprised of a helical electron emissive coil adapted to be directly heated, the middle section of said coil being surrounded by at least one winding layer of a material having a good heat conductivity characteristic.

5. A high frequency generator as defined in claim 1 wherein said cathode is comprised of a

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tube, a helix of electron emissive material on said tube, and a heater coil within said tube.

6. A high frequency generator as defined in claim 1 wherein said cathode is comprised of a bellows-like electron emissive tube, and a heater coil within said tube.

HANS JAKOB VON BAEYER.

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