

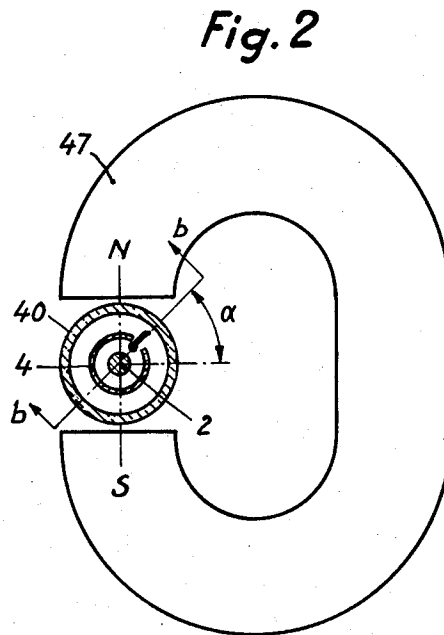
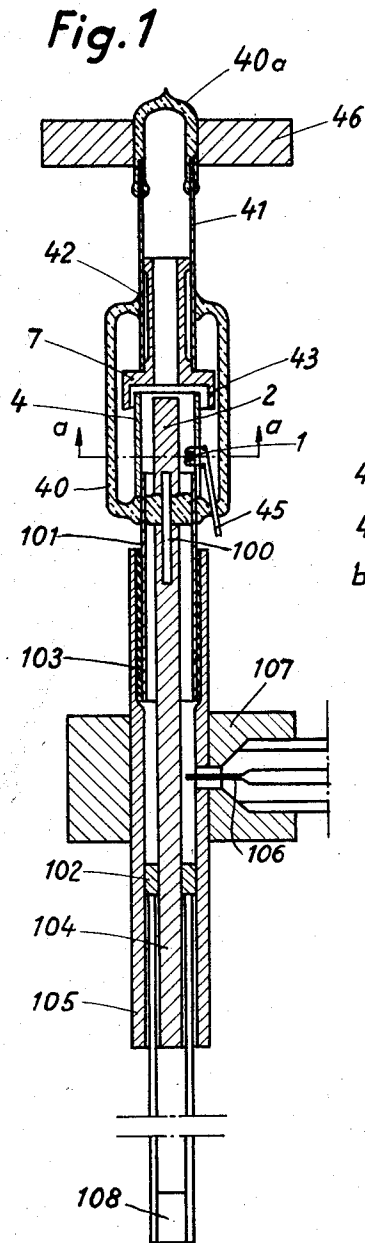
Oct. 7, 1958

J. S. A. TOMNER ET AL
ELECTRON TUBE FOR GENERATING HIGH
FREQUENCY OSCILLATIONS

2,855,532

Filed July 21, 1954

2 Sheets-Sheet 1



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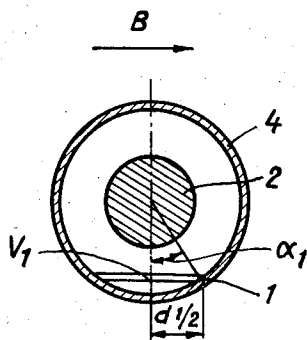
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Fig. 3



$F(\alpha)$

Fig. 5

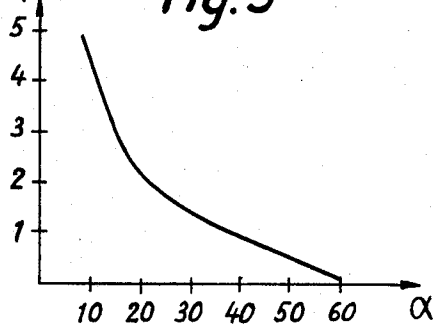


Fig. 6

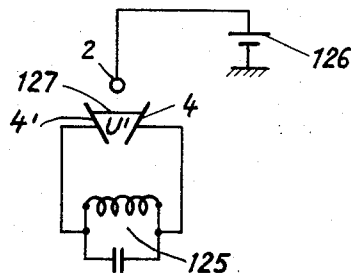


Fig. 4

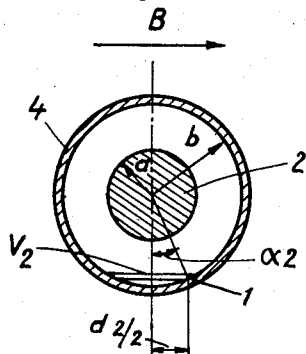
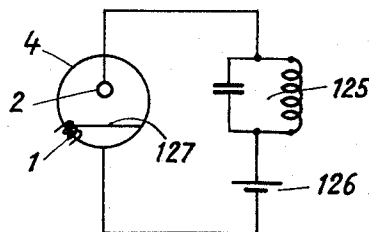


Fig. 7



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ELECTRON TUBE FOR GENERATING HIGH FREQUENCY OSCILLATIONS

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Application July 21, 1954, Serial No. 444,887

Claims priority, application Sweden August 15, 1953

3 Claims. (Cl. 313-157)

This invention relates to an electron tube permeated by a magnetic field for generating high frequency oscillations and particularly a tube of this kind arranged for variable tuning within a wide frequency range.

The principle of the electron tube to which the invention relates is described in the copending U. S. patent application of H. O. G. Alfven and Dag Rommell, Ser. No. 284,978, which is now abandoned. In such a tube the electrons, which are accelerated in an electrostatic field parallel to the magnetic field, exchange energy with a high frequency electric field while oscillating to and fro. The tube comprises means to impart to the electrons a drift movement perpendicular to the electrostatic field.

It is known that the oscillation frequency of the tubes described in the above U. S. patent application 284,978 may be varied by means of varying the field strength of the electrostatic field causing the electrons to oscillate, i. e. the voltage of suitable electrodes.

This method for tuning the tube has however the following disadvantage. The output power of the tube will vary with the frequency, and the voltage sources will be rather complicated.

The object of the invention is chiefly to improve electron tubes of the above described kind, to make them better suited for generating frequency modulated oscillations having a great frequency deviation and good linearity.

The invention relates especially to a further development of the coaxial tube shown in said U. S. patent application Ser. No. 284,978, Figs. 7a and 7b, said coaxial tube being united with a wave guide, a tubular part of which serves as reflector electrode, and the anode being located centrally in said part of the wave guide.

The above described electron tube, the discharge space of which is permeated by a magnetic field, and in which electrons, which are accelerated in an electrostatic field parallel to the magnetic field, exchange energy with a high frequency electric field while oscillating to and fro, comprises at least one cathode, one anode, one cylindric reflector electrode and one collector arranged so that the anode is located centrally in the discharge space limited by the reflector electrode, the collector electrode being located at one end of said discharge space and the cathode at the other end, the electric field formed between the reflector electrode and the anode thus having a component directed perpendicularly to the magnetic field but in the same plane thereof, which component imparts a drift movement to the electrons perpendicular to said field and said component.

The electron tube according to the invention is characterized by means being provided for turning the tube around its axis, which is perpendicular to the field lines of the magnetic field, whereby the oscillation frequency of the electrons and thus the frequency of the generated high frequency oscillations will be changed without the electrode potentials being changed.

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The invention will be closer described with reference to the accompanying drawings, of which

Fig. 1 shows a longitudinal section of a tube according to the invention taken along the line *b-b* of Fig. 2,

Fig. 2 shows a cross-section along the line *a-a* of the tube shown in Fig. 1, the magnet also being illustrated, Figs. 3 and 4 schematically show the electrode system in a tube according to the invention,

Fig. 5 shows a diagram relating to Figs. 3 and 4,

Fig. 6 shows an electrode system of the fundamental type shown in U. S. patent application Ser. No. 284,978 connected to a tuned circuit,

Fig. 7 shows the electrode system of a tube according to the invention, connected to a tuned circuit.

The tube shown in Figs. 1 and 2 comprises within an envelope 40 a cathode 1, located in an aperture in a tube-shaped reflector electrode 4 and a cylindrical anode 2. The inner surface of the reflector electrode 4 and the anode 2 define an elongated discharge space. At the upper end of this discharge space, as shown in Fig. 1 a collector electrode 7 is arranged, while cathode 1 is located at the opposite end of the discharge space. The cathode 1 is so arranged, that a diameter through the cathode forms an angle α with a diameter perpendicular to the magnetic field, as is shown in Fig. 2. The cathode 1, which is supported by the cathode leads 45, is manufactured of tantalum, tungsten or thoriated tungsten, and it is spiralized in the usual manner to increase the emitting surface without increasing the heater current required. The anode 2 is preferably manufactured of tantalum, whereby a gas absorbing getter action is obtained and a special getter may be avoided. The anode is cylindrical, as a round anode gives an almost parabolic voltage distribution if the rest of the electrode system is suitably shaped, as is seen from Fig. 4 of the above mentioned U. S. patent application Ser. No. 284,978.

The shown electrode system with a cylindrical anode coaxially located within a tube-shaped reflector electrode gives an electrostatic field, the voltage distribution of which in a segment plane through the cathode, parallel with the magnetic field, is approximately parabolic for different values of α . The parabolic voltage distribution has the effect, that the oscillation frequency of the electrons will be independent of the oscillation amplitude provided that the electrons pass the same maximum potential.

The collector 7 consists of a copper cylinder and is provided with a collar 43, which surrounds the upper ends of the anode 2 and the reflector 4. The collector is surrounded by a sleeve 41 of Kovar, which is sealed between the envelope 40 and an upper portion 40a of said envelope, but is chiefly free from the collector itself, so that at the centre of said collector, where the glass seal to the envelope 40 is located, a circular space 42 is formed. Thus, the copper collector need not be vacuum tightened towards the sleeve 41, which is an advantage with regard to the different heat expansion coefficients of these materials. The sleeve 41 may be provided with cooling flanges (not shown on the drawing) for increasing the heat removal from the collector 7, which is strongly heated during the operation of the tube.

The reflector electrode 4 is at its lower end prolonged by a sleeve 101, for example of Kovar, which is provided with an insulating tube 103, for example of Teflon, said sleeve being inserted in a coaxial outer conductor 105, thus forming a quarter wave length transformer for high frequency. The anode 2 is over a wire 100 of for example Kovar connected with a coaxial inner conductor 104, Kovar being used to facilitate the leading in of the wires through the glass envelope. The pin 100 is supported by the inner conductor 104 of the coaxial line,

and the tube 101 is supported by the insulating sleeve 103, whereby the envelope 40 can be rotated in relation to the coaxial line 104, 105. The whole tube can be rotated by turning the handle 46 but for facilitating a precise adjustment of the angle α , shown in Fig. 2, the tube may be rotated by means of any suitable lever or gear mechanism. By providing the upper part of the inner and outer conductors 104 and 105 of the coaxial line with an axial slit, the bearing will be resilient, whereby the tube 40 will remain in a selected position after adjustment.

The magnetic field is obtained from a permanent magnet 47, which is shown in Fig. 2 but not in Fig. 1. The pole pieces of this magnet are so high, that a fairly homogeneous field is obtained in the elongated discharge space. Suitably, the height of the pole pieces is made equal to the diameter of the envelope 40, and the lower part of the magnet is placed at the same level as the cathode.

When the tube is operating and under the influence of the outer magnetic field (indicated by B in Figs. 3 and 4) permeating the discharge space, the electrons emitted by the cathode 1 have an oscillatory movement as shown in Figs. 3 and 4, whilst they are imparted a drift movement upwards under the influence of that component of the electrostatic field perpendicular to the magnetic field between the reflector electrode 4 and the anode 2. When the oscillating amplitudes of the electrons have fallen to a fraction of the original amplitude, they hit the collector 7. The generated high frequency oscillations are taken out from the coaxial system 104, 105 by means of a probe located in a holder 107 on the outer conductor 105, and their frequency can be adjusted by displacing the tuning means indicated by 108 and provided with a short-circuiting device 102.

Figs. 3 and 4 schematically show sections through the electrode system in a tube according to the invention and their object is to illustrate how the tube, by partial rotation about its axis relative to the magnetic field B, can be operated at different frequencies with the same anode and reflector voltages. As is stated in the said U. S. patent application Ser. No. 284,978, the following expression is valid for the oscillation frequency of the electrons:

$$f = \text{constant} \frac{V^{1/2}}{d}$$

d being the oscillation amplitude of the electrons and V the highest potential passed by the electrons. In Figs. 3 and 4 the cathode, the anode and the reflector electrodes are indicated by 1, 2 and 4. a and b are the radius of the anode and respectively the reflector electrode. V_1 and V_2 indicate the maximal potential passed by the electrons, d_1 and d_2 their oscillating amplitude, and α_1 and α_2 the angle between a line from the cathode 1 to the middle of the anode and a vertical reference plane through said middle. By turning the tube an angle $\alpha_1 - \alpha_2$ the case shown in Fig. 4 is obtained. A comparison between the Figs. 3 and 4 shows, that such a turning of the tube round its axis, which axis goes through the middle of the anode, changes the maximal potential passed by the electrons from the value V_1 to the value V_2 and the oscillating amplitude of the electrons from the value d_1 to the value d_2 . The oscillation frequency can be expressed in the following manner:

$$f = \text{constant} \frac{V_a^{1/2} [1n(b/a \cos \alpha)]^{1/2}}{b \sin \alpha}$$

V_a being the voltage difference between the anode 2 and the cathode 1. In Fig. 5, the function

$$F(\alpha) = \frac{[1n(b/a \cos \alpha)]^{1/2}}{\sin \alpha}$$

has been drawn for a value $b/a = 2$.

Supposing that the tube is operated at a certain frequency f_1 and the coaxial resonator is tuned to said fre-

quency, the potential difference V_a between the anode and the cathode and the potential of the reflector electrode, which is negative in relation to the cathode, must then be so adjusted, that the right oscillation frequency is obtained for the electrons. If the setting of the short-circuiting device 102 (Fig. 1) is changed so that the coaxial conductor is tuned to a higher frequency f_2 , it is evidently not necessary to change the potential of the different electrodes in order to affect the oscillation frequency of the electrons, but it is only necessary to turn the tube round its axis in the manner shown in Figs. 3 and 4, keeping the said potentials constant. To be able to cover a frequency range of for example 1400-2000 mc./s. in an electric tube made according to the said patent application it is usually necessary to vary the voltage V_a from 1000 to 2000 volts. By varying instead the turning angle α according to the invention, the tube can be operated over its whole tuning range with a negligible change of the applied voltages. The tube according to the invention obviously presents a considerable advantage over the known tube.

The object of Figs. 6 and 7 is to show the difference between the oscillation mode in a tube according to the fundamental embodiment in the U. S. patent application Ser. No. 284,978, shown in Fig. 6, and a tube according to the invention, shown in Fig. 7. In these Figures 1, 2, 4, 4' represent the cathode, the anode and respectively the reflector electrodes. 126 is the source of anode potential, 125 the outer resonance circuit and 127 the oscillation plane of the electrons between the reflector electrodes 4, 4' and respectively within the reflector electrode 4.

A proper phase relation between the oscillating electrons and the high frequency oscillations requires that the transit time from one of the reflector electrodes 4 to the anode 2 in the known tube corresponds to a quarter of a period, whereas in the tube according to the invention it must correspond to a half period. At a given anode voltage and electrode spacing the tube according to the invention will thus oscillate with double the frequency, compared to the known tube. Since the oscillation frequency of the electrons is proportional to the square root of the anode voltage according to the above given formulae, the difference between said two types of tubes can be described so, that for the same frequency and electrode interval the anode voltage of the tube according to the invention is a quarter of the anode voltage of the known tube.

Different modifications of the shown embodiment may be made without the spirit of the invention being departed from.

We claim:

1. An electron tube, the discharge space of which is permeated by a magnetic field, and in which electrons accelerated in an electrostatic field parallel to the magnetic field exchange energy with a high frequency electric field while oscillating to and fro, said tube comprising at least one cathode, one anode, one cylindric reflector electrode and one collector, with the anode located centrally in the discharge space limited by the reflector electrode, the collector being placed at one end of said space and the cathode at the other end, the electric field arising between the reflector electrode and the anode having a component parallel to the magnetic field causing the electrons to oscillate to and fro along a chord parallel to the magnetic field and the electric field having a component directed perpendicularly to the magnetic field, said last mentioned component imparting to the electrons a drift movement perpendicular to said field and said first component, and means for adjusting the relative position of the tube and the magnetic field about the reflector axis, whereby the oscillation frequency of the electrons, i. e. the generated high frequency oscillations can be varied without changing the electrode potentials.

2. A high frequency generator comprising an electron tube having a tubular reflector electrode, a cylindrical

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anode located within said reflector electrode, thereby forming an elongated annular discharge space between the reflector and the anode, an electron emitting cathode located at one end of said discharge space adjacent to the reflector electrode, a collector electrode located at the other end of said discharge space, means for creating a magnetic field directed perpendicularly to the axis of said tubular reflector electrode, the component of the electric field between the reflector electrode and the anode parallel to the magnetic field causing the emitted electrons to oscillate to and fro along a chord of the reflector electrode parallel to the magnetic field, the component of the electric field between the reflector electrode and the anode perpendicular to the magnetic field causing the oscillating electrons to move slowly along the axis of the reflector electrode from the cathode to the collector electrode, and means for varying the angle seen in a plane perpendicular to the axis of the reflector electrodes between a line through the center of the tubular reflector electrode and the cathode, and the magnetic lines of force, whereby the length of the chord along which the electrons oscillate, and, thus, the oscillation frequency is varied.

3. An electron tube having an evacuated envelope, a cylindrical anode extending from one end of the envelope toward the other, a reflector electrode coaxially surrounding and spaced from the anode, a collector electrode at the opposite end of the envelope substantially closing the

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space within the reflector electrode, a concentrated cathode electrode in the reflector electrode adjacent the wall thereof at the end opposite the collector electrode, means directing a magnetic field across the discharge space within the reflector perpendicular to the anode axis whereby it is parallel to a component of the electrostatic field extending from the reflector electrode to the anode, said component imparting to and fro oscillations along a reflector chord to electrons accelerated in the electrostatic field parallel to the magnetic field, a component of the electrostatic field normal to the magnetic field imparting a drift movement to the electrons perpendicular to the electrostatic field and toward said collector electrode, means comprising a tuned coaxial line connected to the reflector and anode forming the oscillation circuit therefor, and means for relatively rotating the tube and magnetic field about the axis of the anode whereby the generated high frequency oscillations may be varied in frequency without changing the electrode potential.

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