Feb. 5, 1946. S. HANSEN 2,394,055

WAVE IMPULSE GENERATOR

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Fig. 1.

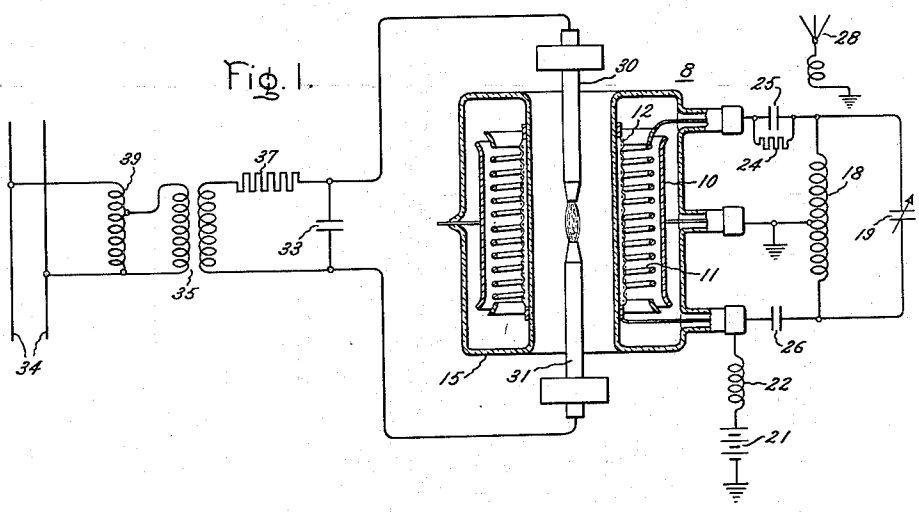
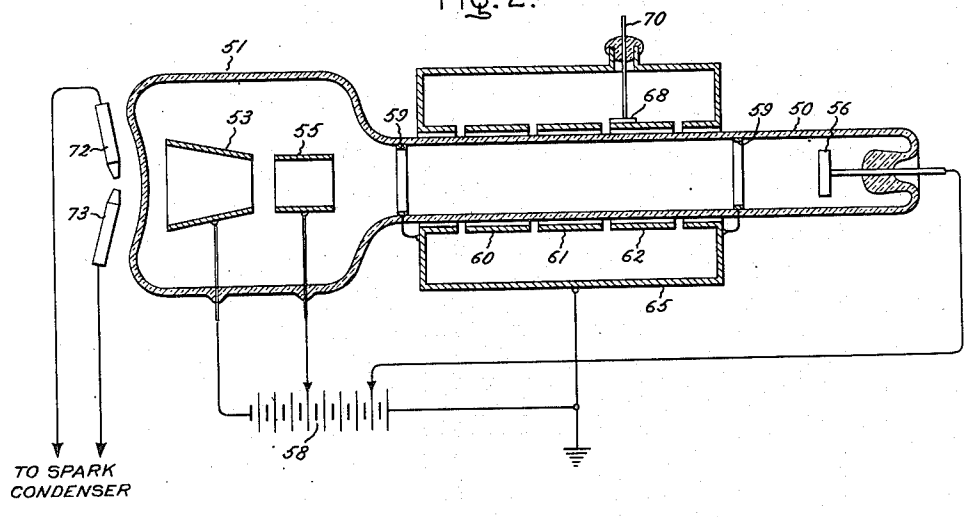


Fig. 2.



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Fig. 3.

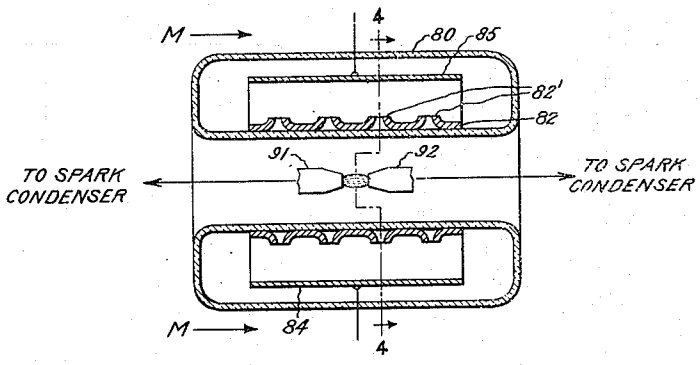
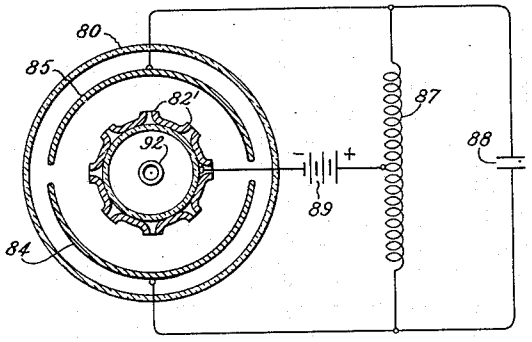


Fig. 4.



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2,394,055

WAVE IMPULSE GENERATOR

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Application November 4, 1941, Serial No. 417,814

10 Claims. (Cl. 250—36)

The present invention relates to improvements in apparatus for the generation of high frequency electro-magnetic wave impulses.

Because of the ease with which radio waves having a wave length on the order of a few centimeters may be sharply directed, methods have been devised to employ such waves in the detection and location of distant objects such as enemy aircraft and the like. In general, the systems utilized in this connection involve the propagation of directed beams of high frequency energy and the reception and analysis of signals produced by the reflection of this energy from the object desired to be located.

Because of inherent limitations in the equipment available for the generation of waves within the extremely high frequency range in question, it has proven difficult to produce wave radiations as powerful as are desired for the purposes under consideration. This difficulty is somewhat mitigated, however, by the consideration that most systems of echo range finding involve the procedure of "pulsing", which requires that the wave-generating apparatus be energized only at intermittent intervals and for very short periods of time. Since the instantaneous capacity of an electronic wave generator is always materially greater than the loading which it could sustain on a continuous basis, it is possible by this means to generate brief signal impulses of relatively very great intensity without loading the generating apparatus beyond a safe limit.

In systems of the kind just referred to a major problem consists in the provision of satisfactory means for performing the pulsing operation; that is, for turning the active parts of the system on and off with the desired rapidity. In general, the methods heretofore employed in this connection involve the step of repeatedly interrupting and reclosing the plate circuit of some form of high voltage discharge tube constituting a key part of the generating apparatus, a procedure which presents numerous technical difficulties.

It is a principal object of the present invention to provide an improved system for pulsed operation of a high frequency wave generator which system does not require plate-circuit switching and is free from the difficulties which attend such switching.

An important feature of the invention consists in the employment of a high frequency tube having a photo-cathode, as distinguished from the more usual thermionic cathode, and means for subjecting such a cathode to very intense light impulses. By this means it is found possible to obtain instantaneous photoemission sufficiently intense to permit the tube thus supplied to operate for a brief interval of time at a signal-generating level greatly in excess of the tube's normal rating and thereafter to be abruptly cut off or at least brought to a condition of low power consumption without any switching operation other than the cessation of the light impulse by which the photoemission is produced. The rapidity of response of such a system is exceedingly great, so that the use of the system permits signal pulses of very limited duration to be developed. This, in turn, allows the peak intensity of the pulsed signal to be relatively enormous without thereby subjecting the generating equipment to the danger of damage from overload.

A still further advantage of a system such as that specified is that it materially reduces the power requirements of the generating equipment over what is needed in a system using a high frequency tube with a continuously energized thermionic cathode. Obviously, a photocathode has no standby power consumption so that the heating current supply required by the thermionic type of electron-emitter may be eliminated.

The invention is considered applicable in connection with tubes operating in the manner of conventional triodes, in magnetrons, and in beam tubes of the so-called velocity modulation type. Doubtless numerous other applications will occur to those working in the radio field.

The features which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the drawings in which Fig. 1 represents schematically a pulsed wave generator suitably embodying the invention; Fig. 2 represents the application of the invention in connection with an oscillator of the so-called velocity modulation type; Fig. 3 shows the application of the invention to a magnetron; and Fig. 4 comprises a sectional view taken on line 4—4 of Fig. 1 and further illustrates a circuit for use with the magnetron of that figure.

Referring particularly to Fig. 1 there is shown a vacuum triode 8 comprising a concentric electrode arrangement which includes a cylindrical cathode 10, a spirally wound grid 11 and an anode 12 which is of reticulate or mesh construction. The various electrodes are enclosed within a toroidally shaped evacuated container 15 which is constituted of a transparent material such as glass, and are connected outside the container

to the elements of a Hartley oscillator. This comprises a tank circuit including an inductance 18 and a condenser 19, these elements being arranged in parallel and being terminally connected to the anode 12 and grid 11. The cathode 10 is connected to an intermediate point of the inductance 18. Plate potential is applied to the anode 12 from an appropriate source 21 through a choke coil 22, and the grid 11 is biased by means of a grid leak resistor 24 and a condenser 25. A blocking condenser 26 is interposed between the plate supply and the tank circuit 18, 19.

With the arrangement specified the apparatus is adapted to generate oscillations upon the passage of an electron stream from the cathode 10 to the anode 12. The wave energy thus developed in the oscillatory circuit 18 and 19 may be employed in a signal-transmitting system by coupling the circuit to an antenna 28 as indicated. In the type of application contemplated for the present invention the antenna 28 may suitably constitute an element of a directional transmitter to be used in aircraft detection or the like.

In an application of the character specified it is imperative that the instantaneous intensity of the generated signal be relatively very great in order to permit effective observations to be made with respect to objects at a considerable distance. Moreover, in order that highly directional effects may be obtained, the radiations employed must be in the ultra-high frequency range. The concurrent fulfillment of these two conditions presents numerous difficulties in that electronic devices which are capable of producing high frequency signals are not inherently adapted to handle large quantities of power. Fortunately, it is possible, and indeed characteristic, in echo range finding systems to use a method of pulsed operation which requires the signal-generating apparatus to be used only intermittently and for very brief intervals of time. Under these circumstances the instantaneous outputs which may be obtained greatly exceed the outputs which could be sustained under conditions of continuous operation.

The present invention is primarily concerned with the provision of means for obtaining pulsed operation of a signal-generating apparatus without incurring the difficulties attendant upon systems which employ the technique of intermittently interrupting the plate supply in order to obtain the desired cessation and re-establishment of operation. In this connection it has been found possible to obtain switching of the desired speed and reliability by making the cathode of the electronic device employed (e. g. the cathode 10 in the arrangement of Fig. 1) of photoemissive character and by exciting the cathode by instantaneous exposure to light impulses of very high intensity. Referring particularly to the construction of Fig. 1, the cathode 10 is provided on its inner surface with a photosensitive coating, for example, a composite coating of antimony and caesium deposited on a nickel base in a manner known in the art. The emissive surface thus provided is excited through the agency of a spark discharge produced between spaced electrodes 30 and 31 which are located within the hollow structure of the device 8. Due to the perforate nature of the anode 12 and of the grid 11, the light developed in the arc stream between the electrodes 30 and 31 has relatively free access to the surface of the cathode 10 and is thus enabled to cause the cathode to develop photoemission.

In order that the electron flow developed within the discharge device 8 may be of sufficient magnitude to serve the purposes of the present invention without concurrent overloading of the electrode structures, means are provided for producing between the electrodes 30 and 31 a spark discharge of high instantaneous intensity but of extremely short duration. This is accomplished by the use of a charge-storage device (e. g. a condenser 33) which is periodically charged from an alternating current source 34, say, of sixty cycle frequency. The condenser is connected to the source 34 through a voltage transformer 35 which serves to impress voltage of relatively great magnitude (for example, 10,000 volts) on the condenser 33 through a current-limiting resistor 37. The excitation of the transformer is controlled through a variable inductance 39 which is connected in shunt with it.

With the arrangement shown and with proper adjustment of the gap between the electrodes 30 and 31, having due regard for the magnitude of the voltage involved, it is possible to assure the occurrence of a breakdown between the electrodes during each cycle of potential variation of the supply source 34. Assuming a low inductance connection between the condenser 33 and the electrodes 30 and 31, the entire energy stored in the condenser during the interval preceding breakdown may be discharged through the gap between the electrodes in a very brief internal of time, for example, one microsecond. Moreover, with practical arrangements the resultant light impulses may readily attain a peak intensity of several thousand watts. Under these circumstances, the effect upon the sensitized surface of the cathode 10 is such as to produce an instantaneous photoemission which is well in excess of one ampere and which under favorable conditions may reach a level of several hundred amperes.

The relatively enormous value of the emitted current makes it possible for high voltages to be impressed between the electrodes of the discharge device 8 without thereby producing a condition of emission-limited operation. In other words, the device may be operated in a space charge limited condition, so that the electron stream may be effectively varied or modulated by the action of the grid 11. Accordingly, during the period in which the photoemission is maintained, the device functions in the manner of a conventonal triode and in such fashion as to develop strong high frequency oscillations in the tuned circuit 18, 19 with attendant signal propagation from the antenna 28.

It is significant to note that photocathodes have heretofore been regarded as useful only for the development of currents on the order of a small fraction of an ampere and that their operation even at these small currents is saturation limited. The fact that these limitations are abrogated by the present invention is a result of the fact that the emitting period is limited to an interval of such brevity that the high instantaneous current flow does not result in overheating or other damage to the cathode.

The resultant pulses of high frequency wave energy as developed in the tank circuit 18 and 19 are very sharply defined and well adapted to the requirements of pulsed signal operation. Moreover, the switching function, that is, the transition from an operative to an inoperative

condition and vice versa, is accomplished in an extremely simple manner which entirely avoids the difficulties of plate circuit switchng as heretofore employed in analogous systems.

The invention is capable of application in connection with other types of high frequency electronic apparatus than that illustrated in Fig. 1, and in Fig. 2 I have illustrated its use in connection with a velocity modulation tube of the general character of those described in W. C. Hahn Patent 2,222,902, granted November 26, 1940, for High frequency apparatus. This comprises an elongated vacuum enclosure having a cylindrical shaft portion 50 and an enlarged bulbous end portion 51. Within the bulbous portion 51 there is provided a cathode 53 in the form of a hollow truncated metal cone which is provided on its interior surface with a photosensitive coating of appropriate character. In proximity to the cathode 53 there is provided an accelerating electrode 55 for projecting electrons released from the cathode toward the other end of the discharge enclosure where they are collected by means of an anode 56 arranged to intercept them. The electrodes referred to are maintained in appropriate potential relationship by external connection to a unidirectional voltage source 58. Additional electrodes 59, which are at a common potential, serve to establish a region of uniform electron velocity along the central portion of the electron path.

The section of the tube 50 between the electrodes 59 is surrounded by a resonant system comprising a series of separate conductive tubular elements or electrodes 60, 61 and 62 and a cylindrical conductive structure 65 concentrically enclosing these elements. The electrodes 60, 61 and 62 are so proportioned that in conjunction with the structure 65, they are enabled to function as sections of a standing wave transmission line having voltage peaks at the gaps which separate the members. In general, excitation of the resonant system thus provided is produced by the reaction of the electrodes and the electron stream traversing the discharge enclosure. According to one point of view, velocity variations are introduced in the electron stream by the electrode 60, these variations are converted into charge density variations as the stream traverses the discharge enclosure, and the latter variations react on the resonant system as the stream passes through the electrodes 61 and 62 to maintain the system in a condition of sustained oscillation. The resultant high frequency electromagnetic wave energy may be coupled out of the enclosure 65 by means of a capacitive connection 68 which terminates outside the enclosure in an antenna 70.

In order to produce pulsed operation of this system in accordance with the present invention there is provided in proximity to the end wall of the enclosure part 51 a pair of spaced sparking electrodes 72 and 73 which are indicated as being connected to a spark condenser. For purposes of simplicity the spark condenser is not illustrated but may be assumed to be of the same character as that shown in Fig. 1. In the intended mode of operation of the apparatus, intermittent light-producing discharges are established between the electrodes 72 and 73 and the instantaneous bursts of emission from the inner surface of the cathode 53 are projected down the axis of the discharge enclosure, being caused to excite the electrodes 60, 61 and 62 while in transit. Accordingly, pulse modulated high frequency waves are delivered to the antenna 70. In this application, as in that previously described, the invention offers the advantage of a greatly simplified pulsing procedure.

In Figs. 3 and 4 there is shown the further use of the invention in connection with a magnetron oscillator. In this case use is made of a toroidal discharge enclosure 80 which contains a generally cylindrical cathode 82 and a pair of mutually spaced semicylindrical anodes 84 and 85 which surround the cathode. A magnetic field produced axially of the enclosure 80 as indicated by the arrows M in Fig. 3 serves to produce orbital motion of electrons released by the cathode 82 and to prevent such electrons from flowing directly to the anodes 84 and 85. By connecting the anodes across a tuned circuit, which is represented in Fig. 4 by the combination of an inductance 87 and a capacitance 88, and by applying a potential between the anode and cathode from a voltage source 89, high frequency oscillations may be obtained through the reaction of the electrode structure upon the orbitally moving electron stream.

As a means for providing controlled emission from the cathode 82 the cathode is made of photosensitive character and is excited by exposure to an intermittent arc discharge produced, for example, between electrodes 91 and 92 located at the axis of the discharge enclosure 80. These electrodes are energized from a spark condenser system (not shown) in the manner previously specified herein. Obviously, in the arrangement indicated only the inwardly directed surfaces of the cathode 82 are exposed to the light radiations developed by the electrodes 91 and 92. In order that the electron emission developed from these surfaces may have access to the space between the cathode and the anodes 84 and 85 the cathode is made perforate character, being preferably provided with a large number of conically shaped embossments 82′ each having a central opening directed toward the surrounding anode structure. The inner surfaces of the various embossments, that is, the surfaces exposed to radiations from the electrodes 91, 92, are photoelectrically activated so that electrons are generated in direct proximity to the various cathode openings whenever the electrodes are energized. Accordingly, pulsed operation of the magnetron is possible in accordance with the principles previously described.

While the invention has been explained by reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the invention. I, therefore, aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, an electronic discharge device having means including a photocathode for producing a stream of electrons, means acting on the said stream to produce useful high frequency effects during the functioning of the discharge device, an agency cooperatively positioned with respect to the said photocathode for producing light impulses of high intensity, and means for intermittently energizing the said agency to produce periodic functioning of said discharge device at an operating level materially above the safe point for continuous operation.

2. In combination, an electronic discharge de-

vice having a photocathode, a collector for electrons emitted by the photocathode and means for influencing electrons flowing between the said cathode and collector, an agency for subjecting the photocathode to light impulses of high intensity, and means for periodically energizing said agency to produce intermittent operation of said discharge device at an operating level materially above the safe point for continuous operation.

3. In combination, an electronic discharge device having means including a photocathode for producing a stream of electrons, means coupled to the said stream to produce useful high frequency effects during periods of excitation of said photocathode, spaced electrodes defining a spark discharge path in proximity to the said photocathode, and means for intermittently creating between said electrodes brief, light-producing discharges of such intensity as to produce from said cathode pulses of photoemission materially exceeding the safe emission limit of said cathode when operated continuously.

4. In combination, an electronic discharge device having means including a photocathode for producing a stream of electrons, means coupled to the said stream to produce useful high frequency effects during periods of excitation of said photocathode, spaced electrodes defining a spark discharge path in proximity to the said photocathode, a charge-storage device connected between the said electrodes and adapted, upon charging, to produce a spark discharge in the said path, and means for intermittently charging and discharging the said charge-storage device to effect periodic excitation of the said photocathode and resultant pulsed operation of said high frequency means.

5. In apparatus for the production of pulsed electromagnetic waves, the combination which comprises an electronic discharge device having means including a photo-cathode for producing a stream of electrons, a high frequency system coupled to the said stream and adapted to be excited thereby so as to generate electromagnetic waves of the desired character, an agency in proximity to the photocathode for producing light impulses of high intensity, and means for intermittently energizing said agency at regular intervals to produce pulsed operation of the said discharge device.

6. In apparatus for the production of pulsed electromagnetic waves of a particular frequency, the combination which comprises an electronic discharge device having means including a photocathode for producing a stream of electrons, a tuned wave-generating system coupled to the said stream and adapted to be excited thereby, said system being resonant at the said particular frequency, an agency for subjecting the said photocathode to light impulses of high intensity, and means for intermittently energizing the said agency to produce pulsed operation of the said discharge device and hence of the apparatus as a whole.

7. In combination, an electronic discharge device having means including a photocathode for producing a stream of electrons, spaced electrodes positioned to be influenced by the stream, a tuned circuit connected between the electrodes and adapted to be maintained in oscillation by the action of the stream, an agency for subjecting the photo-cathode to light impulses of high intensity, and means for intermittently energizing the said agency to produce pulsed operation of the said discharge device and the said circuit.

8. In combination, a vacuum triode having a photo-cathode, a tuned circuit connected to the electrodes of the triode to cause it to function as an oscillator, an agency for producing intense light impulses in proximity to the said photocathode to excite the same, and means for intermittently energizing the said agency to produce pulsed operation of the oscillator.

9. In combination, a discharge device having an elongated enclosure, means including a photocathode for producing a beam of electrons axially traversing the enclosure, a resonant system coupled to the said beam and adapted to be excited thereby so as to generate high frequency oscillations, an agency for producing intense light impulses and for projecting the resultant light on the said photocathode, and means for intermittently energizing the said agency to produce pulsed operation of the said discharge device and the said resonant system.

10. In combination, a magnetron having a centrally disposed photocathode, magnetic means for producing orbital motion of electrons emitted by said cathode, conductive elements arranged circumferentially around the said cathode and coupled to the orbitally moving electron stream produced by it, a resonant oscillatory system having the said elements as component parts thereof, an agency for subjecting the said photocathode to light impulses of high intensity, and means for intermittently energizing the said agency to produce pulsed operation of the magnetron.

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