This invention relates to electrical space discharge devices which are adapted to produce pulses of ultra high frequency oscillations, in which devices the oscillations are derived from the movement of electrons in curvi-linear paths under the influence of a magnetic field, the anode forming one or more closed oscillatory tank circuits therein, the frequency generated being principally determined by the geometry of the anode.

An object of the present invention is the provision of an improved electrical space discharge device of the type hereinabove described and of a method of operating same.

In certain pulsing applications, electrical space discharge devices of the aforementioned type produce oscillations in pulses involving the use of considerable power. An intense magnetic field is required to produce such oscillations. Herefore comparatively large magnets have been employed to obtain such intense magnetic field. In accordance with my invention I am able to produce the required magnetic field without the use of magnets. I accomplish this by means of surges of current of high value in a conductor. This conductor is preferably a straight conductor and may consist of the cathode-heating filament or of the cathode of the electrical space discharge device.

In such pulsing applications, each of the pulses is of comparatively short duration with a comparatively long time interval between successive pulses. It is only during such pulses that the intense magnetic field for producing oscillations is required. Therefore, the surges of current for producing the magnetic field preferably are of the same or approximately the same duration as said pulses, and are synchronized therewith. The amount of current supplied during such surges to establish the desired intense magnetic field may be such that despite the shortness of such surges enough energy is supplied to the cathode, or other conductor, to raise its temperature considerably. During the interval between successive surges this temperature falls. Due to the comparative length of such intervals it becomes feasible to maintain the average temperature within practical limits. This can be accomplished by proper selection of the various constants of the system.

Another object of the present invention is therefore the provision of novel means for establishing the intense magnetic field required for producing the desired oscillations in a system of the type indicated.

A further object of the present invention is the provision of means for establishing a magnetic field of novel configuration, thereby enabling the construction of a novel arrangement of an electrical space discharge device of the type hereinabove indicated which has certain advantages.

Other and further objects of the present invention will become apparent and the foregoing will be best understood from the following description of exemplifications thereof, reference being had to the drawing in which

Fig. 1 is a perspective view of a longitudinal section of an electrical space discharge device embodying my invention, and a schematic diagram of an electrical system in which said device is employed; and

Fig. 2 is a similar view of a modified form of such device embodying my invention, and a schematic diagram of an electrical system employed therewith.

Referring now to Fig. 1, the electrical space discharge device 1 there illustrated is comprised of an envelope 2 which may be made of a block of conductive material, such as copper. This envelope also serves as the anode of the device. Anode 2 is provided with a longitudinal central bore 3 within which is supported substantially at the center thereof a cathode 4. As will be explained in detail hereinafter the cathode 4 is adapted to conduct pulses of current of high peak volume for brief periods of time. To prevent the cathode from becoming overheated it is desirable that the cathode dissipate energy as rapidly as possible during the periods between pulses in order that the temperature of the cathode may be confined within comparatively safe limits. It is therefore desirable that the cathode utilized in this device have the maximum surface with the minimum volume. For this purpose the cathode 4 may be made in the form of a ribbon or may consist of a thin metallic sleeve over a rod of quartz, Alundum, or the like. The cathode 4 is maintained under tension and supported by a pair of conducting springs 5 arranged at opposite ends thereof, said springs in turn being connected with a pair of lead-in conductors 6 sealed through glass seals 7 mounted at the outer ends of envelope 2.

Envelope 2, which serves as the anode of said device 1, is formed so as to provide oscillatory tank circuits which determine the frequency of the oscillations generated in said device. For this purpose a plurality of annular spaced slots 8 are provided in the envelope 2, each of said
slots 8 extending in a plane substantially normal to the longitudinal axis of the cathode. Adjacent
pairs of such slots define between them annular segments 9. Each pair of segments 9 separated
by a slot 8 forms a tank circuit including inductance and capacity. When the aforedescribed
device is energized in the presence of a suitable magnetic field, oscillations are set up
whose frequency is determined primarily by the dimensions and configurations herebefore de-
scribed. The oscillations produced in these tank circuits reinforce each other. These oscillations
may be led out of the device by means of a coupling loop 10 projecting into one of the slots
8. Loop 10 may be connected with a lead-in con-
ductor 11 arranged concentrically within a pipe
12 which may be inserted within an opening
in envelope 2, the pipe 12 being secured in
said opening by a hermetically sealed thread.
Conductor 11 may be sealed in a glass seal 13
mounted at the outer end of pipe 12. An addi-
tional conducting pipe 14 may be fastened to the
pipe 12 outside of the seal so as to form with
the lead-in conductor 11 a concentric line through
which the high frequency oscillations generated
in the device may be conducted away and
utilized.

As has been stated before the electrical space
discharge device here described is adapted to be
used in pulsing applications, and the pulses may be
relatively of short duration, such as, for ex-
ample, of the order of microseconds. In produc-
ing these ultra high frequency oscillations an
intense magnetic field is required during each pulse,
but this field is only required for short periods
of time. In accordance with my invention the
required magnetic field is produced by large cur-
rents passing through the cathode 4, and since
the magnetic field is only required for short per-
iods of time I prefer to utilize surges of current
of the same short duration for producing the
magnetic field. Such surges of current may also
serve an additional purpose.

By utilizing the cathode as the conductor for
the surges of current which establish the mag-
netic field, and by selecting a cathode of suitable
resistance, such surges of current can be arranged
to deliver enough energy to the cathode to raise
the temperature of such cathode sufficiently to
produce greatly increased emission over that ob-
tained during normal operation thereof. This
increase in emission is obtained without any sub-
stantial deleterious effects. I believe that this
avoidance of substantial deleterious effects is due
to the comparatively short duration of such
surges, to the skin effect of the high frequency of
such surges and to other factors. This use of
surges of current to obtain larger emission is
more fully described, and is claimed, in the ac-
companying application of Laurence K. Marshall for
an improvement in the method of operating elec-
trical space discharge devices, Serial No. 457,803,
filed September 10, 1942.

The cathode 4 may be heated to, or below, its
rated operating temperature by any suitable
means such as, for example, current derived from
a battery 15. At this rated temperature the cath-
ode may be incapable of delivering the emission
required for producing the peak pulses. The
surges of current for producing the desired mag-
netic field must be superimposed on the current
supplied by battery 15 to obtain the required in-
creased emissivity. These surges of current may
be derived from the discharge of a fast condenser
16. By a fast condenser 16 I mean a condenser hav-
ing little distributed inductance. Condenser 16
may be charged from any suitable source of di-
rect current such as, for example, a direct current generator, rectifier, battery, or the
like, and a current limiting resistance 17 may be interposed in series with the source of charging
current. Since condenser 16 is adapted to be
discharged a great many times per second I pre-
fer to utilize for controlling the discharge thereof. Since the ordinary vacuum tube relay while capable of handling high
voltages may be incapable of handling the re-
quired amount of current necessary to produce
the intense magnetic field and peak emission
from the cathode 4, I prefer to have condenser
16 discharge into the primary 18 of a closely cou-
plicated air core step-down transformer 20 having
a second winding of a few turns of wire.
The circuit associated with the primary may be a
high-voltage, low-current circuit, while the
secondary will supply the required high current
at a lower voltage. Close coupling between the
primary and secondary is desired in order that
the impedance or leakage inductance may be
confined to a minimum. In order to obtain the
desired close coupling the secondary 21 may con-
sist of one or more turns of a wire which is
nearly wound around the primary 18. The sec-
ondary 21 is connected to cathode 4 in series with
battery 15. Since the usual battery has a large
internal capacitance, it will offer little impedance
to the pulses of current generated in the second-
ary 21. It is preferred that practically all the
energy delivered by the discharge of condenser
16 be supplied to the cathode 4 and that the im-
pedance of the discharge circuit of condenser 16,
outside of the impedance of the cathode 4, be
limited to a minimum.

Electrical space discharge device 1 is designed to
produce oscillations in pulses. Pulsing poten-
tials may be supplied between the anode 2 and
the cathode 4 from any suitable source, such as
a pulsing device 22. The surges of current to be
supplied to the cathode 4 for establishing the
magnetic field and for producing increased emis-
sion are preferably synchronized with these
pulsing potentials. For this purpose vacuum tube
relays, or some other suitable controls, of the discharge of condenser 16 may be connected
to the pulsing device 22. A phase control device 23 may be interposed between the pulsing device 22 and the
electrical space discharge device 1. This phase
control device 23 may be utilized to properly time the application of pulsing potentials in relation
to surges of current derived from condenser 16.

In the illustrated pulsing system each peak
pulse may have a duration of the order of a microsecond, there being approximately 1000 such
pulses per second, each pulse consisting of oscil-
lations of high frequency such as, for exam-
ple, from about 300 to 1500 megacycles. The
condenser discharge circuit may therefore have
a time constant of the order of a microsecond.
The time interval between surges of energy
to the cathode by condenser 16 will be of the order of 1000 microseconds and the dura-
tion of each of such surges of energy relative to
the time between such surges will be approxi-
mately of the order of 1 to 1000. It is of course
apparent that these constants may be varied with-
in considerably wide limits depending upon the
particular conditions to be met. For example,
the ratio between the duration of said surges and the time between such surges may be as low as
1 to 100 and practically may be as high as one.
to several thousands. Of course it is to be understood that a steady current may be used to produce the desired magnetic field instead of surge currents.

The discharge of condenser 16 is adapted to send a large pulse of current through the cathode 4. The maximum current derivable from the discharge of condenser 16 is approximately

$$I_{\text{max}} = \frac{V}{L}$$

where $V$ = voltage of condenser, $C$ = capacity of condenser and $L$ = the inductance of the circuit including that of the cathode. By careful design $L$ may be as low as $10^{-7}$ henry; $C$ may be $\frac{1}{10}$ of a microfarad, and preferably larger; and $E$ may be 5000 volts, hence

$$I_{\text{max}} = 5000 \sqrt{\frac{10^{-7}}{10}} = 5000 \text{ amperes}$$

Under such conditions a field of from 2000 to 5000 gauss is readily attained. It will also be apparent that the emission obtained under these conditions from any suitable filament will be high and therefore that tube 1 will provide a large output.

As will be readily understood by those versed in this art an electron emitted from the cathode 4 will be drawn towards the inner surface of one of the segments 8. However, due to the concentric magnetic field established by the current flowing through cathode 4, this electron will be deflected in a direction parallel to the cathode towards an adjacent segment 8. For a particular field strength, in the present instance determined primarily by the particular cathode current, and a definite voltage between the anode and the cathode, oscillations are generated in a manner similar to that occurring in a multiple plate magnetron. The output power can be taken off by the coupling loop 16 and delivered to the concentric line wave guide.

The magnetic field produced in this manner rises to a maximum and decreases to zero. Hence, for a single discharge from condenser 16 there may be two points at which the value of the magnetic field is suitable for maximum generation of oscillation. However, the voltage applied to the oscillating circuit through the pulsing device 22 may be regulated so that the maximum generation of oscillations is obtained at the time when said maximum field is established. It will be seen therefore that either one pulse of oscillation for each discharge will be produced, or a double pulse for each discharge will be produced.

In Fig. 2 there is illustrated a modified form of electrical space discharge device and of a system used in connection therewith. In the arrangement shown in Fig. 2, the anode 2 of electrical space discharge device 1 forms a plurality of tank circuits, each of the tank circuits defining separate oscillating regions. In the electrical space discharge device 26 of Fig. 2 the anode 21 forms but two tank circuits and two oscillating regions, but these oscillating regions are relatively much longer and enable the development of considerable power. By utilizing such an arrangement the energy of the oscillation in electrical space discharge device 26 may be easily transferred to the output coupling loop 25. Additional advantages are also obtained from this arrangement as will be seen from the following description thereof.

The anode 27 of electrical space discharge device 26 illustrated in Fig. 2 is provided with two parallel helical slots 28 and 29 in place of the separate radial slots 8 of the device of Fig. 1. These helical slots 28 and 29 are formed like a double screw thread, the two slots being adjacent each other and spiraling along the inside of the anode 27. These slots define between them a helical segment 30 and another helical segment 31. The segments 30 and 31 might be considered as the walls of an elongated trough which has been twisted in the form of a helix. Two separate oscillating regions are thereby formed: one separate oscillating region consisting of the segment 30 and the segment 31 and the slot 28 therebetween, and the other oscillating region consisting of the segment 31 and the segment 30 and the slot 29 therebetween. These two oscillating regions are each relatively long and serve to reinforce one another.

In the arrangement of Fig. 2 in addition to the magnetic field produced by the energy derived from the discharge of condenser 16, an additional means is provided for producing a second magnetic field extending parallel to the cathode. This second magnetic field may be generated by current from any suitable source of current supply 30' which is passed through a coil 31 arranged about the tube 2, the strength of this field being controlled by any suitable means, such as a rheostat 32 arranged in series with the source of current 30'. The first mentioned field deflects electrons emitted from the cathode in a direction longitudinally of the cathode. The second field imparts an additional deflection of the electron in a direction concentrically about said cathode. The combination of the two fields produces a spiral magnetic field which upon proper selection of the parameters will be approximately parallel to the spiral of segments 29. In this arrangement a slight change in the strength of one of the fields relative to the other will produce a considerable change in the output. Thus, a simple means for modulating the output is provided. Any suitable modulation device 3 may be arranged in series with said cathode and having components of said field lying at right angles to the longitudinal axis of said cathode.

While I have described specific embodiments of my invention, it will be apparent that numerous modifications may be made therein without departing from my invention. For example, tube 1 may have its anode made of a plurality of shaped lamina arranged to form a structure similar to that shown in Fig. 1, and joined together in any suitable fashion, as by soldering. Of course it will be apparent that many different circuits may be devised to cooperate with such tubes in generating oscillations. Likewise numerous other modifications will become obvious from the foregoing description. Accordingly, it is desired that the appended claims be given a broad interpretation commensurate with the scope of this invention within the art.

What is claimed is:

1. An electronic device adapted to cause movement of electrons in curvilinear paths under the influence of a magnetic field, said device comprising an elongated cathode, a plurality of helical anode elements arranged about said cathode substantially concentric therewith, and means for establishing a magnetic field having its lines of force enclosing said cathode and said elements of said field lying at right angles to the longitudinal axis of said cathode.
2. An electronic device adapted to cause movement of electrons in curvilinear paths under the influence of a magnetic field, said device comprising an elongated cathode, a pair of elongated helical anode elements arranged in the form of a double screw thread enclosing said cathode, and substantially concentric therewith, and means for establishing a magnetic field having its lines of force enclosing said cathode and having components of said field lying at right angles to the longitudinal axis of said cathode.

3. An electronic device adapted to cause movement of electrons in curvilinear paths under the influence of a magnetic field, said device comprising an elongated cathode, a plurality of helical anode elements arranged about said cathode substantially concentric therewith, and means for establishing a magnetic field having its lines of force enclosing said cathode, and having certain components of said field lying at right angles to the longitudinal axis of said cathode, and other components lying in a plane parallel to the longitudinal axis of said cathode.

4. An electronic device adapted to cause movement of electrons in curvilinear paths under the influence of a magnetic field, said device comprising an elongated cathode, a plurality of helical anode elements arranged about said cathode substantially concentric therewith, means for establishing a magnetic field having spiral lines of force enclosing said cathode, said lines of force being substantially normal to the anode elements.

5. An electronic device adapted to cause movement of electrons in curvilinear paths under the influence of a magnetic field, said device having a plurality of elements therein including a cathode and a plurality of anode elements arranged in a row adjacent said cathode, said cathode being in the form of an elongated conductor, electrical energy storage means, means for storing energy in said electrical storage means, and a circuit for discharging said electrical storage energy means through said elongated conductor to establish a magnetic field having its lines of force enclosing said elongated conductor, and having components of said field lying at right angles to the longitudinal axis of said conductor.

6. An electronic device adapted to cause movement of electrons in curvilinear paths under the influence of a magnetic field, said device comprising an elongated cathode, a plurality of anode elements arranged in a row extending lengthwise of and adjacent to said cathode, and means for establishing a magnetic field having its lines of force enclosing said cathode and having components of said field lying at right angles to the longitudinal axis of said cathode, said means including an electrical energy storage means, means for supplying energy to said electrical energy storage means, and a circuit for discharging said electrical energy storage means through said cathode.

7. An electronic device adapted to cause movement of electrons in curvilinear paths under the influence of a magnetic field, said device comprising an elongated cathode, an anode element forming path of a tank circuit adjacent said cathode, electrical energy storage means, means for charging said electrical energy storage means, and a circuit for discharging said electrical energy storage means through said cathode and a magnetic field extending through said cathode to establish a magnetic field having its lines of force circling about said cathode, and to raise the temperature of said cathode.

8. An electronic device adapted to cause movement of electrons in curvilinear paths under the influence of a magnetic field, said device comprising an elongated cathode, an anode element, and means for establishing a periodically fluctuating magnetic field, said means including means for periodically supplying surges of current to said cathode.

9. An electronic device adapted to generate oscillations derived from the movement of electrons in curvilinear paths under the influence of a magnetic field, said device comprising a plurality of electrodes including a cathode element and an anode element adjacent thereto, said cathode being an elongated conductor, and means for establishing a magnetic field for the generation of oscillations, said means including means for supplying sufficient current to said elongated conductor to produce a magnetic field sufficiently intense to generate said oscillations.

10. An electronic device adapted to generate oscillations derived from the movement of electrons in curvilinear paths under the influence of a magnetic field, said device comprising a plurality of electrodes including a cathode element and an anode element adjacent thereto, said cathode being an elongated conductor, and means for establishing a magnetic field for the generation of oscillations, said means including means for supplying sufficient current to said elongated conductor to produce a magnetic field sufficiently intense to generate said oscillations.

11. An electronic device adapted to cause movement of electrons in curvilinear paths under the influence of a magnetic field, said device comprising a plurality of electrodes including a cathode element and an anode element adjacent thereto, said cathode being an elongated conductor, and means for establishing a periodically fluctuating magnetic field for the generation of oscillations, said means including means for periodically supplying surges of current to said elongated conductor.

CHARLES G. SMITH.

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Certificate of Correction


CHARLES G. SMITH

April 13, 1948.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Column 8, line 1, claim 7, for the word "path" read part; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 8th day of June, A. D. 1948.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.