

Sept. 23, 1958

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2,853,623

X-RAY PULSE GENERATOR

Filed June 4, 1957

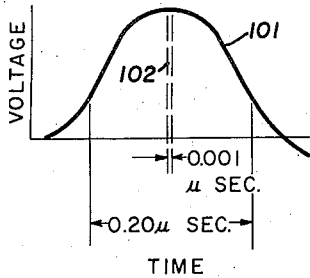


Fig. 2.

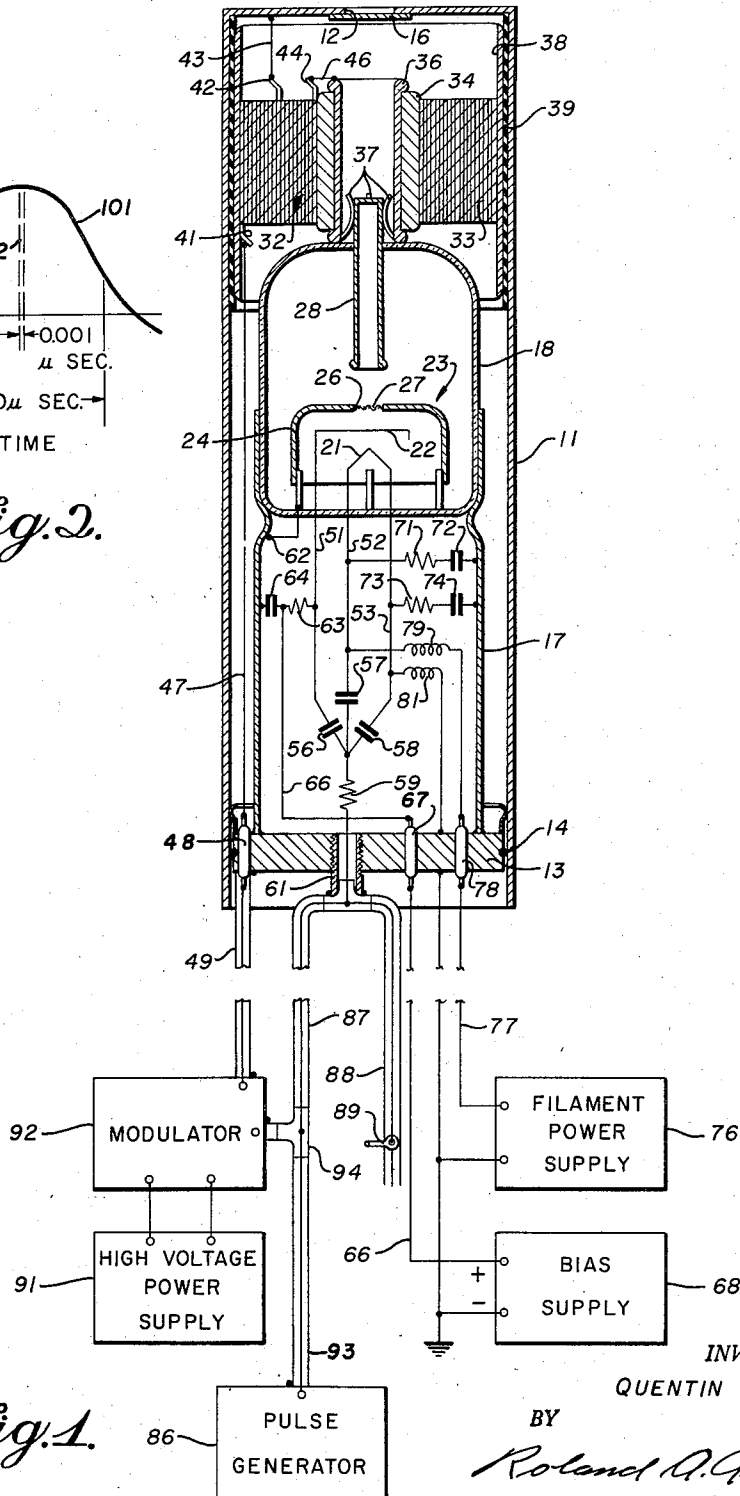


Fig. 1.

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2,853,623

X-RAY PULSE GENERATOR

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Application June 4, 1957, Serial No. 663,558

6 Claims. (Cl. 250—102)

The present invention relates to an X-ray generator and, more particularly, to a portable generator of pulses of X-rays having a short time duration per pulse.

Certain applications of X-rays require pulses of such rays having a short time duration, in some instances, as short as 10^{-9} second (one millimicrosecond). Among the known types of X-ray generators are a few capable of pulsed operation, but to achieve a time duration of the order of one millimicrosecond requires a new approach to the X-ray source and to the associated pulsing components.

The usual X-ray source, now in use, is of the Coolidge type which is generally bulky and expensive, and requires a bulky and expensive high voltage pulsating power supply. The present invention provides a simple, portable, and inexpensive X-ray source utilizing a commercial type television receiving tube and a small auto-transformer. To power such source of pulses of X-rays only simple and conventional components are required.

It is therefore an object of the present invention to provide a new and improved X-ray generator.

Another object of the invention is to provide a new and improved pulsed X-ray generator.

A further object of the invention is to provide an X-ray generator of pulses having a time duration of the order of one millimicrosecond.

Still another object of the invention is to provide an X-ray generator capable of high frequency pulsed operation for developing a millimicrosecond pulse of such rays.

A still further object of the invention is to provide a portable and inexpensive generator of X-rays.

Other objects and advantages of the invention will be apparent in the following description and claims considered together with the accompanying drawing, in which:

Figure 1 is a cross sectional view of a source of X-rays with associated circuitry shown in schematic block form; and

Figure 2 is a waveform of voltage occurring during operation of the invention of Fig. 1.

Referring now to the drawing in detail, Fig. 1 in particular, there is provided an elongated cylindrical housing 11, closed at one end except for a centrally disposed opening 12 and opened at the other end. A base plate 13 is provided within the opened end of the housing 11 with a seal 14 suitably mounted therebetween. As a protection for the operator of the device, both the housing 11 and base plate 13 are constructed of a diamagnetic material having a high absorption characteristic for X-rays, such as brass. A thin closure plate 16 is suitably mounted to cover the opening 12 and is fabricated from a material having a low absorption characteristic for X-rays, such as aluminum or copper.

A cylindrical shield 17 of a conductive material, such as copper, is suitably mounted on the base plate 13 and extended coaxially within the housing 11. Such shield 17 provides suitable support for an electron vacuum tube 18. A number of high voltage vacuum tubes used prin-

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cipally in television receivers, such as the 6BD4A, 6BG6G, and others, produce X-rays when operating voltages higher than the commercial rating for such tube is applied and are still capable of withstanding considerable over-voltages upon pulsed operation. The elements of a typical tube 18, a 6BD4A as selected for illustration in the drawing, comprise a filament 21, a cathode 22, a grid structure 23 having an inverted cup-shaped shield support 24 covering the cathode and filament with an electron collimating opening 26 across which a grid 27 is extended, and a hollow tubular anode 28 having a closed end extended through the envelope of the tube. Such tube elements are suitably mounted in the stated relationships with the envelope of the tube 18.

A pulse type auto-transformer 32 is provided within the cylindrical housing 11. A winding 33 of the auto-transformer 32 comprises a thin conducting foil wound spirally with an interleaved thin layer of insulating paper, in the manner of the windings taught in U. S. Patent 2,577,707, issued December 4, 1951, to Q. A. Kerns et al. for a Pulse Transformer. A hollow cylinder 34 of magnetizable material, such as powdered iron, is disposed as a core for the auto-transformer 32 with the winding 33 mounted thereon. Suitably mounted within the opening of the cylinder 34 is a tube 36 of conductive material having clamping fingers 37 which engage and make electrical contact with the extended anode 28 of the tube 18. A sleeve 38 of magnetizable material is disposed between the winding 33 and the housing 11 to provide a low reluctance path for the magnetic field established by the winding and minimize the effect of a short-circuited one-turn winding presented by the housing in relation to the winding. To electrically separate the sleeve 38 from the housing 11, a thin layer 39 of insulating material is disposed therebetween.

The single winding 33 of the transformer 32 is provided with an outer end tap 41, an intermediate tap 42 connected to the housing 11 by a conductor 43, and an inner end tap 44 connected to the tube 36 by a conductor 46. A conductor 47 is connected to the outer end tap 41 and extended through an insulator 48 disposed in the base plate 13 where an external connection is made to the center conductor of a coaxial cable 49. The cathode 22 is provided with an electrical lead which extends through the envelope of the tube 18 and connects with a conductor 51. Such conductor 51 is extended substantially coaxially with respect to cylindrical shield 17 toward the base plate 13. Also, the filament 21 is provided with two leads extended through the envelope of the tube 18 and connected to two conductors 52, 53, respectively. Each of the conductors 51, 52, 53 is respectively connected through separate blocking capacitors 56, 57, 58 to a single resistor 59, which is, in turn, connected to the central conductor of a coaxial connector fitting 61 suitably extended centrally through the base plate 13. A conductor 62 is connected between the cylindrical shield 17 and a lead extended from the grid structure 23 through the envelope of the tube 18. To provide a suitable cathode bias to the tube 18 and normally prevent conduction, a series circuit comprising a resistor 63 and capacitor 64 is connected in such order between the conductor 51 and the cylindrical shield 17 with another conductor 66 connected to the junction of such circuit elements and extended through an insulator 67 in the base plate 13. Externally of the housing 11 there is provided a bias supply 68 with the negative terminal grounded and the positive terminal connected to the conductor 66. The filament conductor 52 is connected to the cylindrical shield 17 through a series circuit comprising a resistor 71 and a capacitor 72, in such order, and a similar resistor 73 and a capacitor 74 are series-connected between the shield and the other filament conductor 53. A filament

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power supply 76 is provided with one output terminal directly connected to the grounded base plate 13 and the other output terminal connected by a conductor 77, which is extended through an insulator 78 in the base plate, to one filament conductor 52 through a radio frequency choke coil 79. To complete the connections to the tube 18 a second radio frequency choke coil 81 is connected between the other filament conductor 53 and the base plate 13.

In the description set forth in the preceding paragraph, it is to be noted that the cylindrical shield 17 serves two purposes, other than support for the tube 18, in that it is an outer conductor of a coaxial line system (the inner conductor of which is the cathode and filament circuitry) and is an element providing electrical isolation between the filament-cathode circuitry and the anode. Also, the resistor 59 prevents oscillations in the cathode-filament circuitry after the application of each pulse when the inherent impedance of such circuitry is insufficient to provide suitable damping.

The output of a conventional pulse generator 86 of millimicrosecond pulses is connected to one end of a coaxial cable 87, the other end of which is connected to the fitting 61 with the central conductor of the cable and fitting suitably joined electrically and the outer conductor connected to the grounded base plate 13. Also, there is extended from the junction of the coaxial cable 87 and the fitting 61 a coaxial stub 88 having a variable short-circuiting plunger 89 at the extended end to provide control of the duration of a pulse at the fitting.

To provide anode potential to the tube 18 a high voltage power supply 91 is connected to a conventional modulator 92 having the output connected to the coaxial cable 49. A coaxial cable 93 is extended from the output of the pulse generator 86, or, as illustrated, from a coaxial cable fitting 94 included in the cable 87, to an input of the modulator 92 to supply the modulating voltage. Finally, it is to be noted that for improved heat dissipation and electrical insulation the housing is filled with an insulating transformer type oil (not shown).

In operation, with the connections and relationships of the elements as described in the foregoing, a negative pulse at the output of the pulse generator 86 results in a pulse applied to the modulator 92. A voltage is then developed at the output of the modulator 92 and is impressed upon the transformer 32. A positive voltage (see waveform 101 of Fig. 2) is then applied across the tube 18. Conduction through the tube 18 is prevented for a major portion of the applied positive voltage by the grounded grid 27 and the positive voltage applied to the cathode by the bias supply 68. For suitable operation it is required that current flow through the tube 18 for a substantially short period (indicated at lines 102 of Fig. 2) during which the voltage at the anode is at a maximum value. To accomplish such operation, the well-known inherent time delay characteristics of coaxial cables are utilized and the leading edge of the negative pulse of the pulse generator 86 is impressed upon the cathode 22 of the tube 18 at substantially the time of maximum voltage at the anode 28. Thus the length of coaxial cable 87 is readily determined as a function of the delay times of the coaxial cable 93, the modulator 92, the coaxial cable 49, and the transformer 32. With the arrival of the negative pulse at the cathode 22 of the tube 18, the positive bias from the supply 68 is overcome so that the tube conducts very heavily and X-rays are produced at the anode 28. The negative pulse of voltage transmitted by the coaxial cable 87, also, proceeds the length of the coaxial stub 88. Since the stub 88 is short-circuited by the plunger 89, the voltage is reflected in opposite phase to cancel the negative pulse at the coaxial fitting 61. In such manner the cathode 22 of the tube 18 is returned to the voltage of the bias supply 68 to render the tube non-conductive prior to the termination of the output pulse of the pulse generator 86. Thus it is readily apparent that

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the time of conduction of the tube 18 is dependent upon the time required for the voltage to travel the length of the stub 88 and return and that the production of X-rays is limitable to extremely short periods of time.

As an example, it has been found that a substantial amount of X-rays have been developed in one millimicrosecond pulses by mounting the 6BD4A tube 18 and the pulse transformer 32, as described, within the housing 11, which has a diameter of approximately three inches and a length of approximately ten inches. The pulse generator 86 supplies pulses of 30 millimicrosecond duration with an amplitude of approximately 500 volts (negative) at a repetition rate of 60 pulses per second. The combination of the high voltage power supply 91, modulator 92, and auto-transformer 32 provides an operating potential 101 of 20 kilovolts with a duration of about 200 millimicroseconds (see Fig. 2) for the tube 18. To maintain the tube 18 in a nonconductive state for a major portion of the duration of the operating potential 101 the bias supply 68 impresses a voltage having a value of 300 volts (positive) upon the cathode 22.

It is readily apparent from the foregoing that the present invention is highly portable and simple in construction and operation. The device set forth above has been found particularly suitable for testing and maintaining counting equipment of high energy particles, phototube analysis, and the production testing of phototubes. Also, a valuable feature of the invention is the availability from the pulse generator of a synchronization pulse which has a definite time relationship with output pulse of X-rays thereby providing a manner in which a highly accurate measure of delay time present in amplifiers and radiation detectors may be made.

While the salient features of the present invention have been described in detail with respect to a single embodiment, it will be apparent that many modifications may be made within the spirit and scope of the invention and it is, therefore, not desired to limit the invention to the exact details set forth, except insofar as they may be defined in the following claims:

What is claimed is:

1. In a pulsed X-ray generator, the combination comprising a vacuum tube having at least an anode, grid, and cathode, voltage means connected between said anode and ground and having an output value substantially greater than rated operating value of said tube, said grid connected to ground, a source of voltage having a positive value with respect to ground connected to said cathode, and a source of pulses having an output value negative with respect to ground and a magnitude substantially greater than the positive value of said source of voltage capacitively coupled to said cathode whereby pulses of X-rays are developed at said anode.

2. In a pulsed X-ray generator, the combination comprising a vacuum tube having at least an anode, grid, and cathode, voltage means connected between said anode and ground and having an output value substantially greater than rated operating value of said tube, said grid connected to ground, a source of voltage having a positive value with respect to ground connected to said cathode, a source of pulses having an output value negative with respect to ground and a magnitude substantially greater than the positive value of said source of voltage capacitively coupled to said cathode, and means coupled to said cathode to cancel the negative value of pulse from said source of pulses within a millimicrosecond of application whereby X-rays are developed during said millimicrosecond at said anode.

3. In a pulsed X-ray generator, the combination comprising a vacuum tube having at least an anode, grid, and cathode, pulsed voltage means connected between said anode and ground and having a peak output value substantially greater than rated operating value of said tube, said grid connected to ground, a source of voltage having a positive value with respect to ground connected

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to said cathode, a source of pulses having an output value negative with respect to ground and a magnitude substantially greater than the positive value of said source of voltage, delay means connected to said source of pulses and capacitively coupled to said cathode, said delay means having a delay time substantially equal to a rise time of pulses at said pulsed voltage means, and means coupled to said cathode to cancel the negative value of pulse from said source of pulses within a millimicrosecond of application whereby X-rays are developed during said millimicrosecond at said anode.

4. In a pulsed X-ray generator, the combination comprising a cylindrical housing having one end closed by a window pervious to X-rays and the other end sealed by a base plate, a vacuum tube supported by a shield disposed coaxially within said housing and mounted on said base plate, said vacuum tube having an anode, grid, and cathode with the grid connected to said shield, a high voltage transformer mounted within said housing adjacent said anode and having a single winding with an outer terminal, intermediate terminal, and inner terminal, said inner terminal connected to said anode and said intermediate terminal connected to said shield through said housing and base plate, pulsed voltage means connected between said outer and intermediate terminals for developing a positive voltage with respect to ground at said anode substantially greater than rated voltage for said tube, a source of voltage having a positive value with respect to ground connected to said cathode, and a source of pulses having an output value negative with respect to ground and a magnitude substantially greater than the positive value of said source of voltage capacitively coupled to a conductor extended coaxially through said shield, said conductor connected to said cathode whereby pulses of X-rays are developed at said anode.

5. In a pulsed X-ray generator, the combination comprising a cylindrical housing having one end closed by a window pervious to X-rays and the other end sealed by a base plate, a vacuum tube supported by a cylindrical shield disposed coaxially within said housing and mounted on said base plate, said vacuum tube having an anode,

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grid, and cathode with the grid connected to said shield, a high voltage transformer mounted within said housing adjacent said anode and having a single winding with outer, intermediate, and inner terminals, said inner terminal connected to said anode and said intermediate terminal connected to said shield through said housing and base plate, pulsed voltage means connected between said outer and intermediate terminals for developing a positive voltage with respect to ground at said anode substantially greater than rated voltage for said tube, a source of voltage having a positive value with respect to ground connected to said cathode, a source of pulses having an output value negative with respect to ground and a magnitude substantially greater than the positive value of said source of voltage, delay means connected at one end to said source of pulses and coupled at the other end to a conductor extended coaxially through said shield, said conductor connected to said cathode, and means coupled to said cathode for cancelling the output of said source of pulses after a predetermined period of time.

6. An X-ray generator comprising a vacuum tube having an anode and a cathode with an intermediate control electrode, first and second power supply means connected in series opposition with the first thereof having a potential in excess of that of said second and of the rated operating voltage of said tube, means connecting a positive terminal of said first power supply to said tube anode and a negative terminal of said second power supply to said tube cathode, means connecting said tube control electrode to the juncture of said power supplies, and input means connected to said tube cathode for applying thereto short duration voltage pulses of a negative polarity for driving said tube to conduct at a potential in excess of rated tube potential whereby X-rays are produced at said tube anode.

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