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Abstract

Full Text

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PHYSICS

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A GENERATOR WITH A WATER DIELECTRIC FOR PRODUCING INTENSE PULSES OF FAST ELECTRONS AND HARD BREMSSTRAHLUNG X-RADIATION

(Presented by Academician Yu. B. Khariton on March 5, 1970)

To obtain very intense flashes of hard X-rays with a duration of several tens of nanoseconds, it is necessary to use comparatively high voltages and large electron currents. In the energy range 2-6 MeV, the X-ray intensity is approximately proportional to the electron energy to the power 3.4. To provide electron currents of tens and hundreds of kiloamperes, the internal resistance of the voltage source must be reduced as much as possible. This is achieved by using sections of coaxial lines and by reducing the inductance of the discharge circuit through the use of high-strength dielectrics. In recent years several types of installations have been proposed and implemented in practice for obtaining very short pulses of fast electrons and X-rays. In the works of A. S. Denholm ([1]), E. A. Abramyan, O. P. Pecherskii, et al. ([2]), a coaxial line—a conductor in compressed gas—charged to a voltage of 3-7 MV by means of an electrostatic generator or a Tesla resonant transformer with coupled circuits was used for this purpose.

Fig. 1. Schematic section of the generator.
C_1—capacitance of the Marx generator; C_2—capacitance of the capacitor with a water dielectric; L—circuit inductance; P_1, P_2—spark gaps/switches; 1—high-voltage input; 2—conductor; 3—body; 4—cathode lead-in tube; 5—accelerating tube; 6—cathode; 7—anode.

The dimensions of a high-voltage pulse generator and its internal resistance can be appreciably reduced if materials with a large value of the dielectric constant ε are used for insulation. Several investigations are known in which well-purified water free of foreign impurities ($\varepsilon = 80$) was used as the dielectric to create

low-inductance high-voltage capacitor sources. In work ([3]), for experiments with exploding wires, capacitors with a water dielectric for a voltage of 500 kV were constructed. In works ([4,5]), low-inductance capacitor circuits with water insulation for a voltage of 250 kV were used to obtain large pulsed currents and strong electromagnetic fields. Capacitors with a water dielectric are charged by a pulsed voltage. With a pulse duration of several microseconds, the electric strength of water approaches the strength of such excellent dielectrics as transformer oil ($2 \div 5 \cdot 10^5$ V/cm). The small volume resist–

···the water (10^6–10^7 ohm · cm) is not a limiting factor here, since the loss of the energy stored by the capacitor during the short electrical pulse is small.

The authors of the present work have constructed and tested a generator with a dielectric of pure water, intended for producing short pulses of fast electrons and hard bremsstrahlung X-ray radiation. The main elements of this device are shown in the schematic drawing of Fig. 1.

The storage unit is a cylindrical reservoir of stainless steel, on which a high-voltage input **1** is mounted. The capacitor with water dielectric C_2 is formed by the cylindrical conductor **2** and the grounded casing **3**. The lower end of the conductor has a hemispherical shape and forms, with the cathode lead **4** of the pulsed accelerating tube **5**, the discharge gap P_2.

The generator operates as follows: through the spark gap P_1 the pulse circuit C_1L charges the capacitor with water dielectric C_2. Upon breakdown of P_2 this capacitor, which at the same time constitutes a coaxial line, discharges into the tube. Electrons from the autocathode **6** are accelerated by the high-voltage field, and an intense flash of hard X-ray radiation arises at the plane anode **7**. If the anode plate is replaced by a window of thin titanium or beryllium foil, the stream of fast electrons can be emitted into the atmosphere.

The storage unit with water dielectric was powered by the Marx pulse circuit described in work ([6]). The discharge capacitance C_1 of the circuit was 6200 $\mu\mu$F, the inductance L was 20 μH, and the discharge voltage was 3 MV. The coaxial line with water dielectric has a length of 50 cm. Its capacitance C_2 is approximately equal to the capacitance C_1 of the Marx generator. This ensures practically complete transfer to the storage unit of the energy stored in the pulse circuit. The charging time of capacitance C_2 to full voltage (3 MV) is 0.7 μsec. With a resistance of the water dielectric of 1–3 kΩ, the voltage drop across capacitance C_2 during the charging time does not exceed a few percent.

Replacing the gaseous dielectric by water reduces the propagation velocity of the electric wave along the line by a factor of 9. Its wave impedance is reduced by the same factor. The total internal resistance of the water storage unit (including the resistance of the spark gap P_2) is estimated at 10 ohms. Under similar conditions the amplitude of the electron current through the accelerating tube lies within 70–120 kA. The X-ray dose at 100 cm from the target is 5–10 roentgens for a pulse duration of 60 nsec.

In direct discharges into the pulsed X-ray tube of the capacitive pulse circuit of work ([6]), the dose at a distance of 100 cm from the target lay within 4-8 roentgens for a pulse duration of 0.6-0.8 μsec. Thus, the use of a water storage unit increased the dose rate by more than an order of magnitude, owing to the shortening of the pulse duration and the increase in electron current.

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Note: Figure translations are in progress. See original paper for figures.