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Publication Date
1960-10-10

UCRL 9269

UNIVERSITY OF CALIFORNIA

Ernest O. Lawrence Radiation Laboratory

BERKELEY, CALIFORNIA

9269

UCRL-9269

UNIVERSITY OF CALIFORNIA
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Contract No. W-7405-eng-48

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ABSTRACT

A nanosecond light source based on a corona discharge started by field emission has been developed for attachment to scintillation counters.

These individual light sources, placed to illuminate each phototube and fired by a pulse generator through splitting transformers and cable delays, have facilitated the coincidence timing of an array of photomultiplier detectors.

Pulse generation, a pulse-splitting transformer, light-source construction, and timing properties, as well as spectral intensity are discussed. An optical attenuator designed for the source is described.

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The coincidence timing of an array of photomultiplier detectors has been facilitated by use of a light-pulse generation system for simulating nuclear events. The system consists of a pulse generator, pulse-splitting transformers, cable delays, and individual light sources placed to illuminate each phototube.

Figure 1 illustrates the arrangement. It is desired to simulate an event by producing a pattern of light pulses in appropriate time sequence at the various phototubes. For example, consider the hypothetical pattern, shown in Fig. 2, of an event in which simultaneous pulses illuminate Phototubes 1 and 3, whereas Phototubes 2 and 4 receive pulses with relative delays of 2 and 18.5 nsec. As a matter of convenience, the time delays to and from the patchboard shown in Fig. 1 can be equalized; in such a case, to set up the pattern in Fig. 2, one would insert a minimum-delay patch cable in Channels 1 and 3, (e.g., 2 nsec), and in Channels 2 and 4 delays of 2 and 18.5 nsec plus the minimum(thus, 4 and 20.5 nsec).

It is clear that the time jitter of any one of the pulses relative to the pattern must be minimized. The pulse-generating system secures timing accuracy by generating a single high-level pulse and distributing it to the lamps via splitting transformers and coaxial lines. Thus the voltage pulse pattern at the lamps is inherently jitter-free. The recurrence rate of the pattern, on the other hand, need not be precise. Usually, the patterns are generated during beam-off intervals. When the pulse generator is switched on, the pattern recurs at a rate of about 100 pulses/sec.

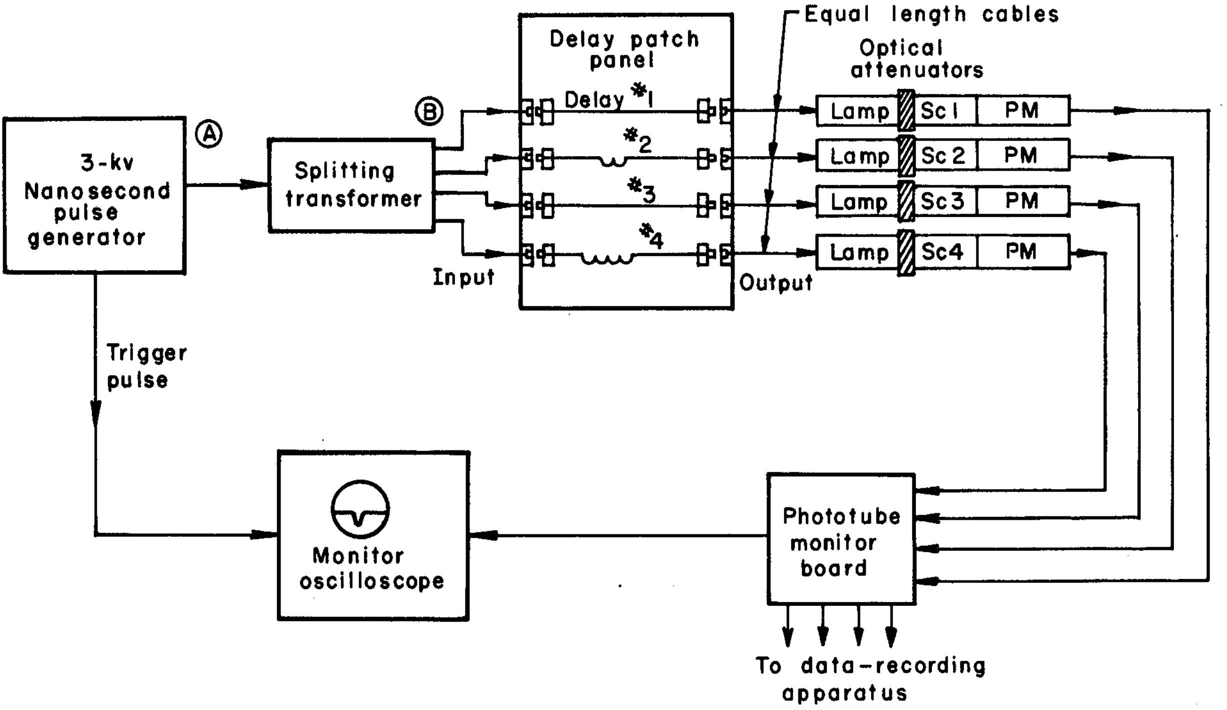

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Fig. 1. Corona lamp simulation of a nuclear event.

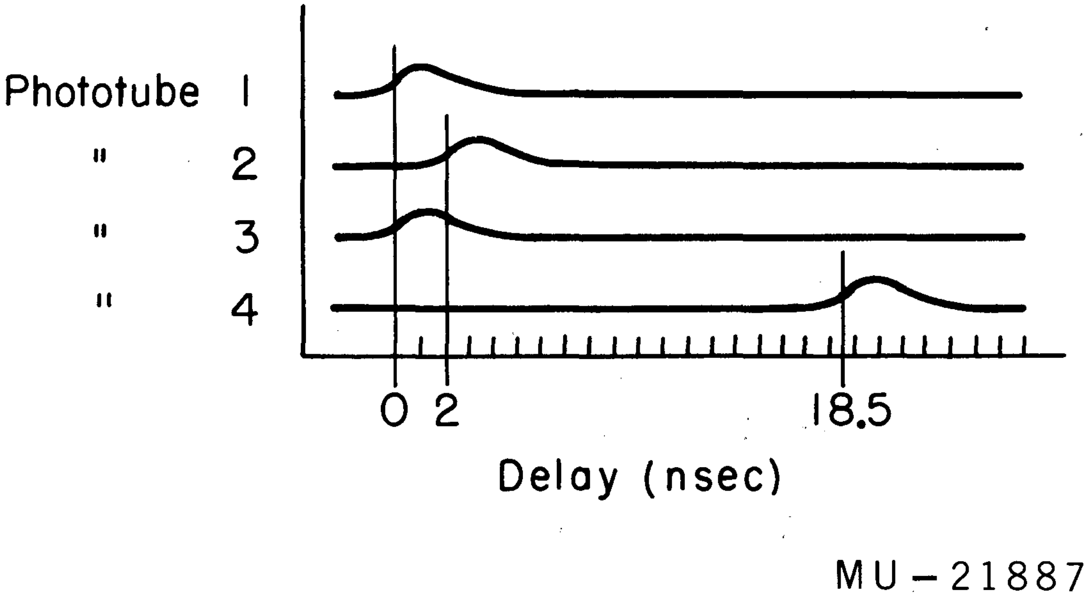

Fig. 2. Illustrative pattern of pulses.

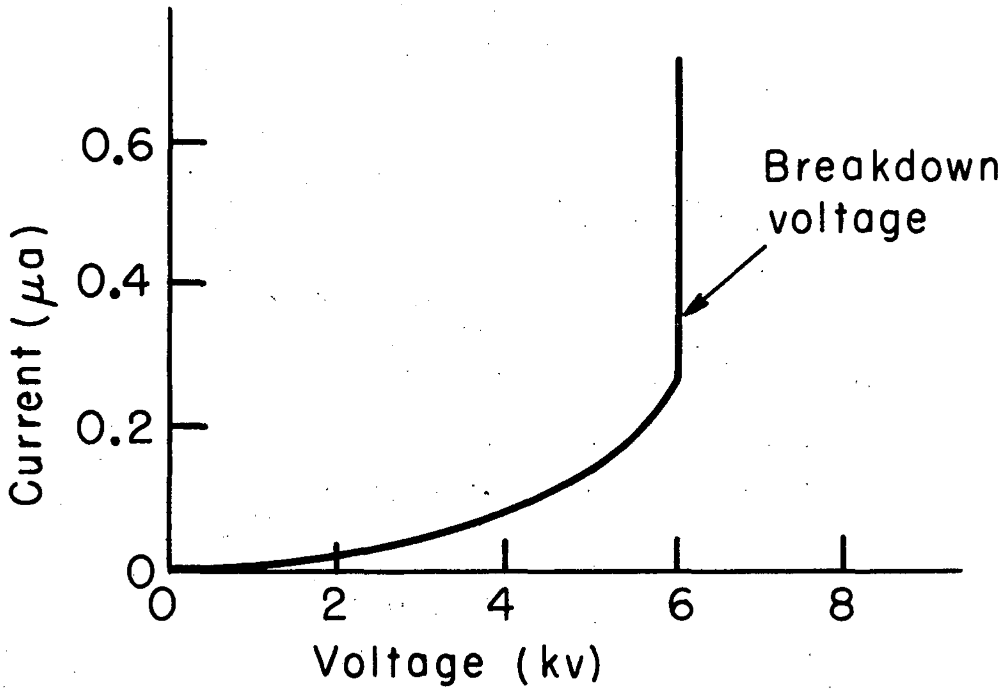

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Fig. 3. Typical current-voltage curve characteristic for mercury capsule.

Trigger pulses, noted in Fig. 1, are derived by transformer coupling from the high-level pulse and are useful in starting oscilloscope sweeps in advance of the phototube signals and as fiducial marks along the sweep. Delay in the signal cables and in the phototube (approx 50 nsec) is usually sufficient to allow for sweep-starting time.

PULSE GENERATOR

The electrical pulses are generated by switching a charged coaxial cable into an output transmission line of matched impedance (51 ohms). A mercury capsule[*] in a constant-impedance oil-filled enclosure is the switch. Figure 3 shows typical current-voltage characteristics for such a switch prior to electrical breakdown. Polarity has little effect on the current-voltage characteristic. A simplified schematic diagram of the pulse generator is shown in Fig. 4.

The capsule relay contact is not vibrated to produce contact closure. Instead, the voltage on the charging cable periodically rises to the breakdown potential and a spark occurs. Pulses that have the shape shown at (a) in Fig. 5 are produced at about 100 pulses/sec.

After several hours of operation, it is desirable to redistribute mercury on the contact surfaces; a coil is provided to vibrate the relay contacts for the purpose. The high-voltage supply and current-regulation

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[*] The capsules used were obtained from the Western Electric, 275-C, and from C.P. Clare and Company, HG-1003 mercury-wetted contact relays. A few capsules have relatively high leakage currents. These are not used in the pulse generator, but may be adequate for other uses.

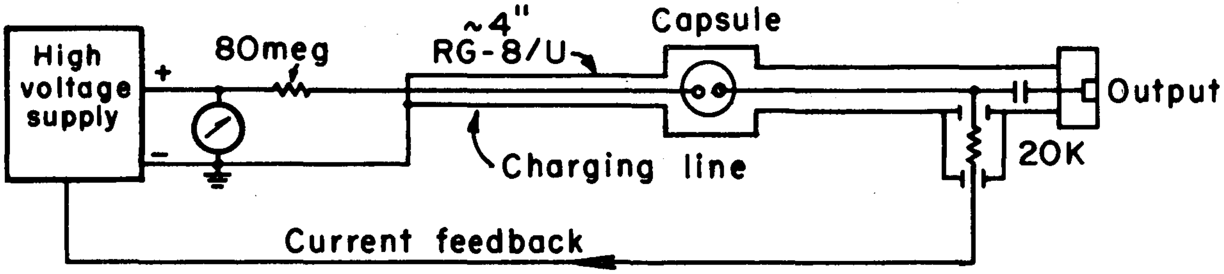

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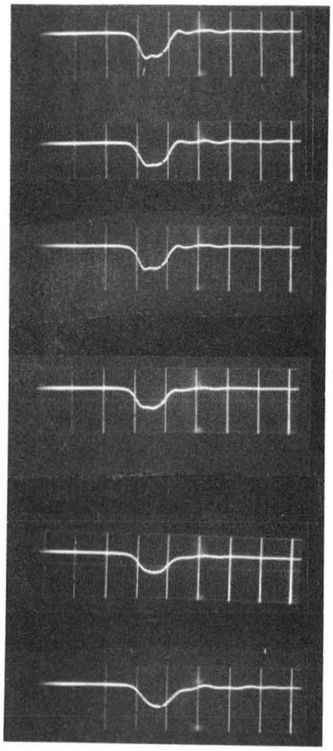
Fig. 4. 3 kv nanosecond pulse generator simplified schematic.



sweep speed = 2 nsec/cm

(a) The 3000-v pulse output from the generator.

(b) One of the four 1500-v outputs from the splitting transformer.

(c) A 3000-v generator pulse after passing through 22 ft. of RG-8/U.

(d) Pulse (a) After passing through 76 ft. of RG-8/U. Amplitude is about 2400 v. The amplitude loss is 20%.

(e) Pulse (a) After it passes through 55 ft. of RG-55/U. The amplitude loss is 25%.

(f) Pulse (a) After passing through two splitting transformers cascaded, plus 55 ft. of RG-55/U. Amplitude is 540 v. With no loss the amplitude would have been 750 v.

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Fig. 5. Wave shapes for some combinations of generator, transformers and cables.

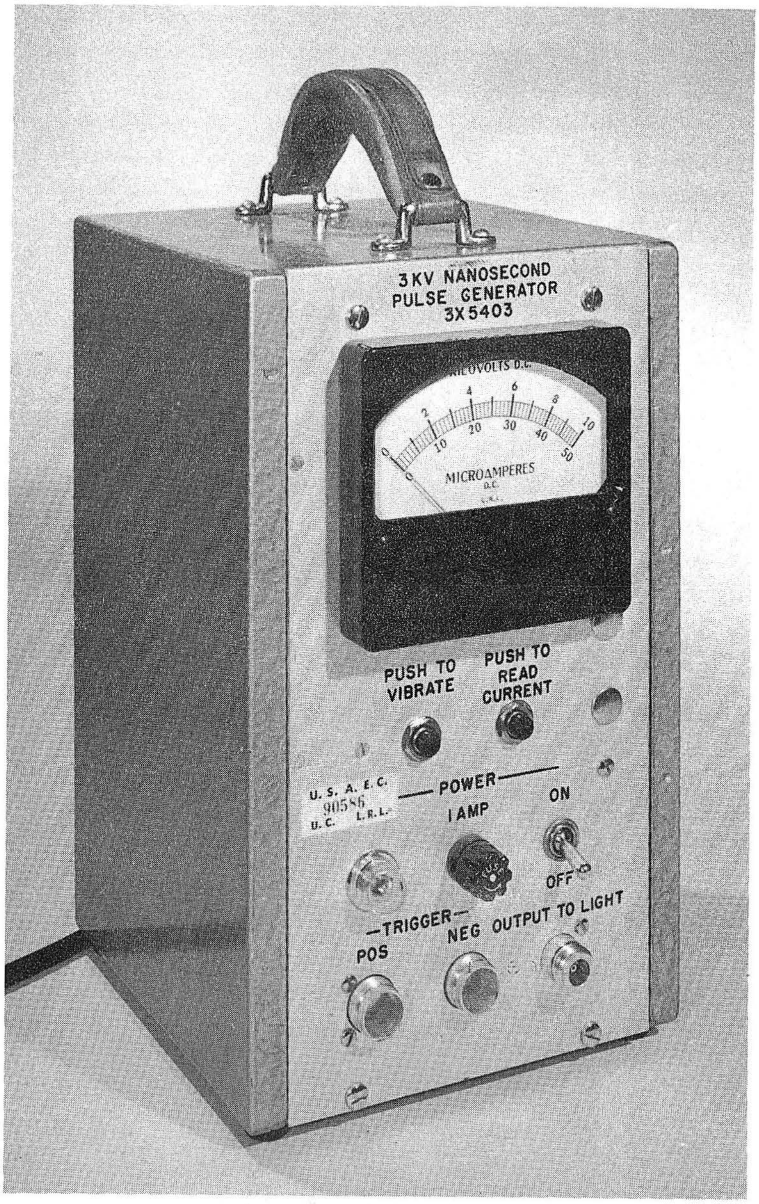

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Fig. 6. 3 kv nanosecond pulse generator.

circuitry is all solid state, with a power consumption from the 60-cycle supply of 4.8 watts. Sixteen generators of the 3X5403 type (Fig. 6) have been built for the application discussed here.

SPLITTING TRANSFORMERS

The input and output impedances of the splitting transformer are 51 ohms. Four equal and synchronous outputs are provided at just half the input voltage. Thus, one transformer can feed four others to produce sixteen identical signals at 1/4 the voltage level of the primary pulse generator. The rise time of the transformers is adequate for an additional cascade, from which there would be 64 output channels available at 1/8 the generator voltage. There is some loss in rise time and amplitude in the transformers, but it is less than the loss in cables that are used to delay and distribute the pulses. The transformer is constructed of four equal lengths (1.6 nsec) of miniature 51-ohm coaxial cable (RG-174/U). The series-parallel connection of the four cables may be seen in the photograph of the transformer, Fig. 7. Two of the four cables have a voltage pulse along the shield length, and are wound on a ferroxcube 102 toroid 1-in. in diameter to raise the impedance of this shunt path. A pulse-inverting transformer of similar construction has been used also with some of the light sources.

Figure 5 shows the wave shapes for some combinations of generators, transformers, and cables. RG-9/U cable has been used for moderate delay, RG-55/U for short delay or patch cables. Styroflex cable of 1-in. diameter has been used for 150-nsec delay, and would be satisfactory for delay up to a microsecond. GR-type 874 connectors, or type N connectors, are used with the RG-9/U cable, and BNC connectors with the RG-55/U cable.

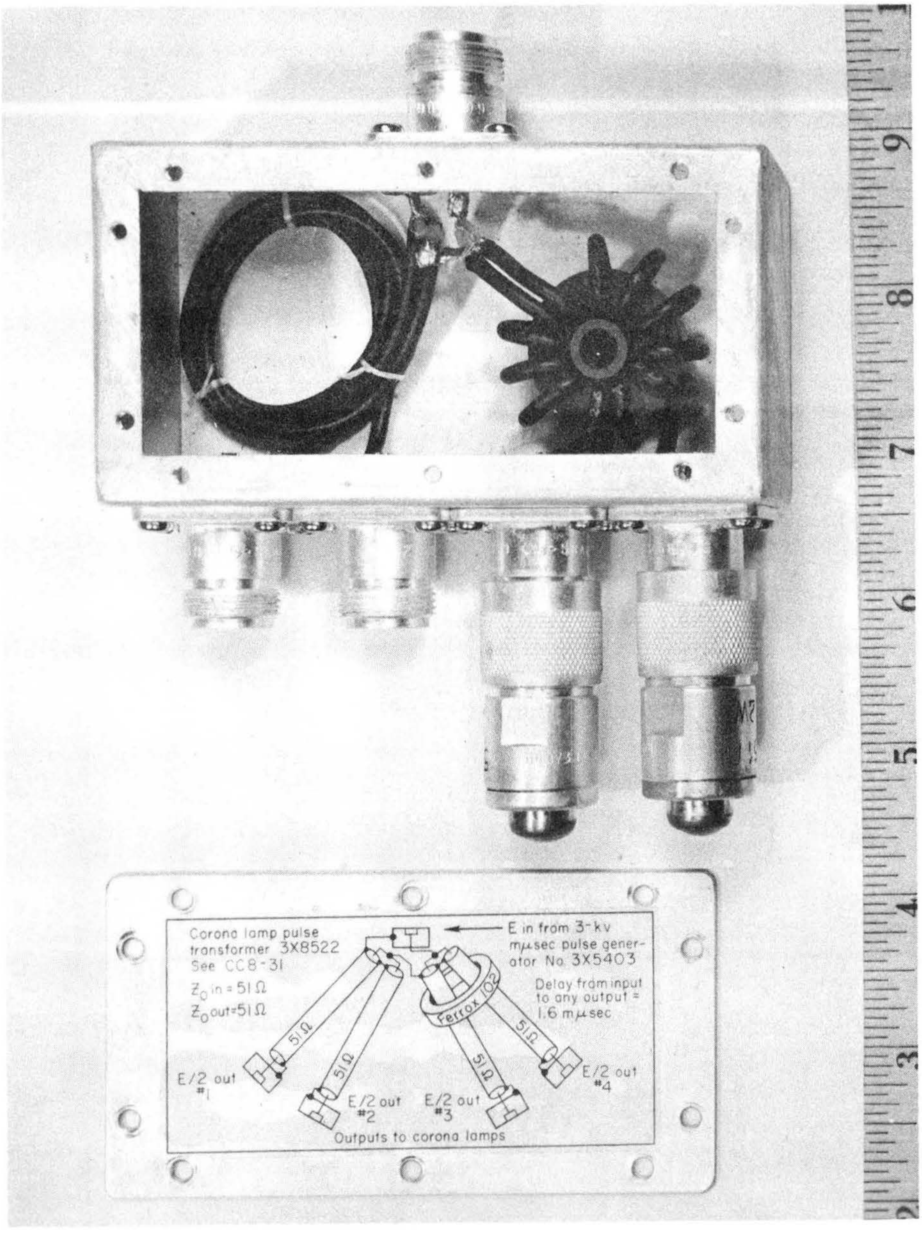

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Fig. 7. Pulse splitting transformer.

The generator, transformer, and cabling system have been maintained in coaxial configuration throughout in order to keep spurious radiation from other circuitry. (RG9/U and RG55/U are the double-shielded versions of RG8/U and RG58/U.)

CORONA LAMPS

The lamp construction has been based on the idea of securing a corona discharge at the tip of a tungsten wire touching a dielectric. Glass has been successfully used for the dielectric, resulting in the construction shown in Fig. 8.

The 2-nsec voltage pulse is applied to the tungsten wire. If the electric field is sufficiently high, field-emitted electrons initiate the corona discharge which is the source of light. Negative polarity on the wire gives a lower threshold voltage than positive polarity, and less amplitude fluctuation at a given voltage.

The light-pulse wave shape has been measured in detail* for a lamp similar to the one shown in Fig. 9, but pressurized to 1 atm hydrogen and driven directly from the 3kv pulse on a terminated 50-ohm line. Figure 10 shows the result. The width at half maximum is about 1 nsec. It should be noted, however, that the light pulse could be somewhat shorter than 1 nsec because of time-resolution limitations in the sampling phototube.

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*The method of measuring the light pulse shape by using a gated 1P21 phototube has been described by F.A. Kirsten, Fast-Pulse Technique in Nuclear Counting, UCRL-8706, February 12, 1959, p. 2, part 1 and 2.

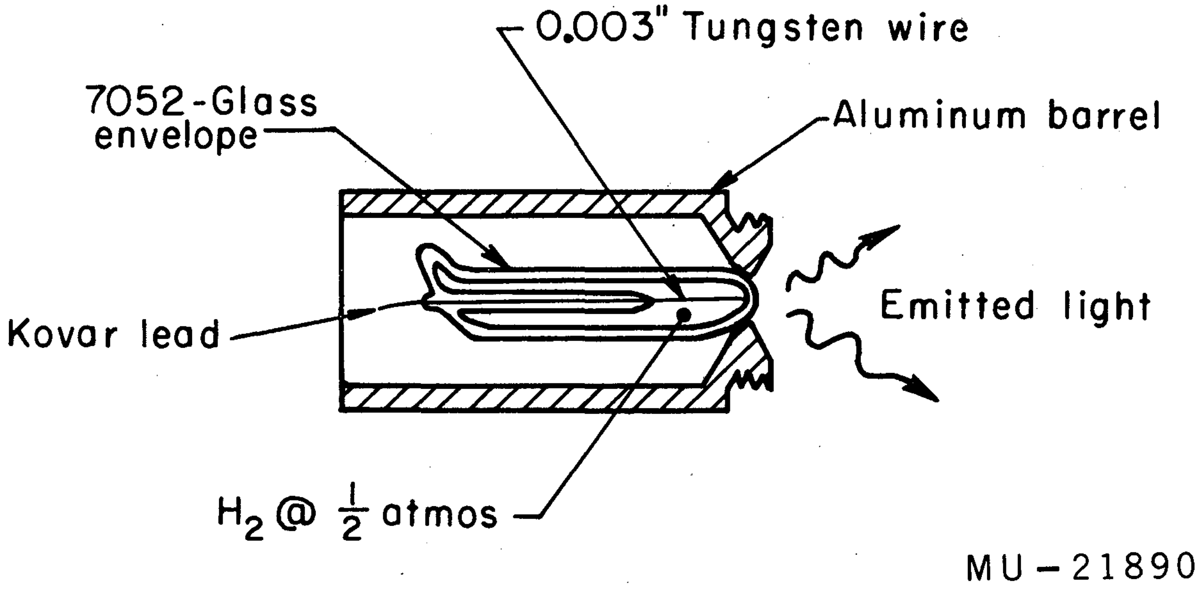

Fig. 8. Corona lamp (two times actual size).

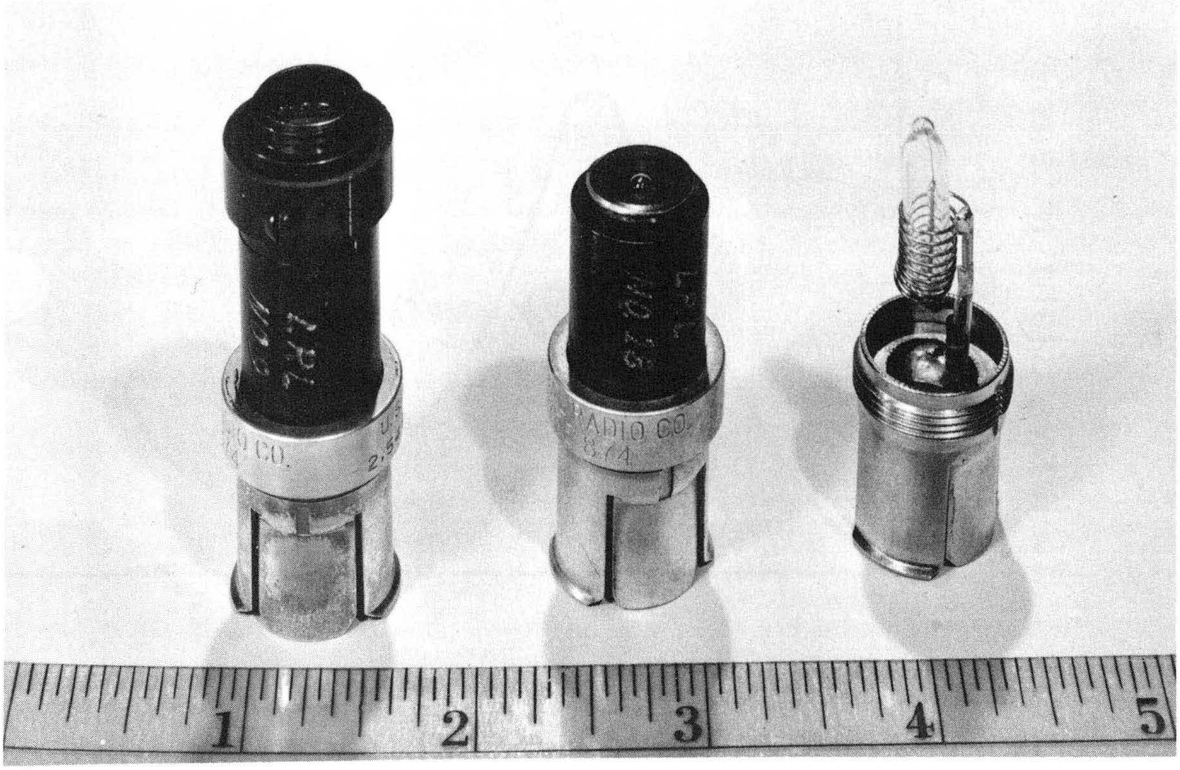

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Fig. 9. Photograph of corona lamps. Lamp on the left has the adjustable polaroid attenuator attached.

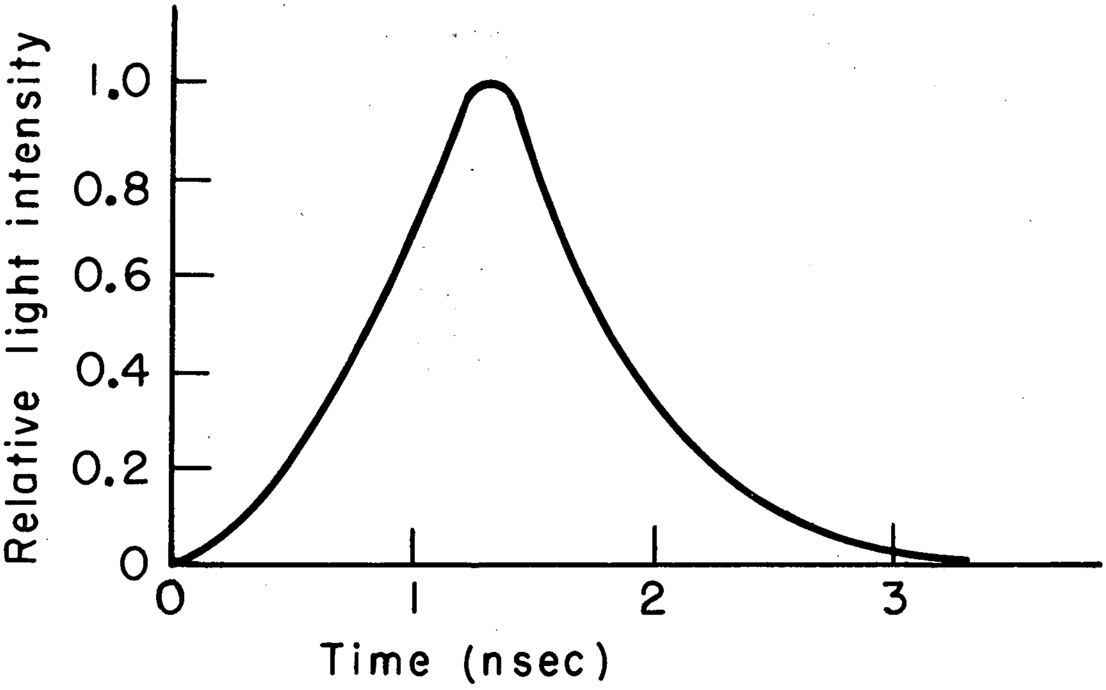

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Fig. 10. Corona lamp light-pulse shape.

The optical spectrum has been examined with a Bausch & Lomb diffraction grating spectrometer set to a slit width of approx 100 A, and viewed by an AMPEREX 56 AVP phototube. Figure 11 shows the spectrum obtained, after correction for phototube response, grating and mirror efficiency, and solid angle. The light appears blue to the dark-adapted eye.

It was desirable to reduce the operating voltage of production lamps. Two measures were taken. First, the pressure was set at 1/2 atm (lower pressures lengthen the light pulse). Second, a small inductance coil was placed in series with the lamp, almost doubling the available voltage. The coil may be seen in Fig. 9, which also shows the 51-ohm terminating resistor shunting the input connector. The effect of the coil on the light pulse length is small; however, the pulse can be lengthened by adding still more inductance. Recently, we have made a lamp design using barium titanate as the dielectric, anticipating a lower operating voltage because of the higher dielectric constant of the titanate.

Figure 12 shows light intensity as a function of pulse voltage for the glass corona lamp and also for the barium titanate design. The barium titanate unit is viewed from the tungsten wire side. It is shown in Fig. 13. To date, life tests on the barium titanate units have been limited to 150 hours at 100 pulses/sec. The operation for this time is stable with an amplitude jitter less than 10%. The envelope contains hydrogen at a pressure of 1/2 atm. A lower pressure gives more light output and good amplitude stability but lengthens the decay time of the light.

Decay times of 15 to 30 nsec have been observed at millimeter pressures. Under high vacuum, the light output is impracticably small. Further work is in progress with the titanate lamp.

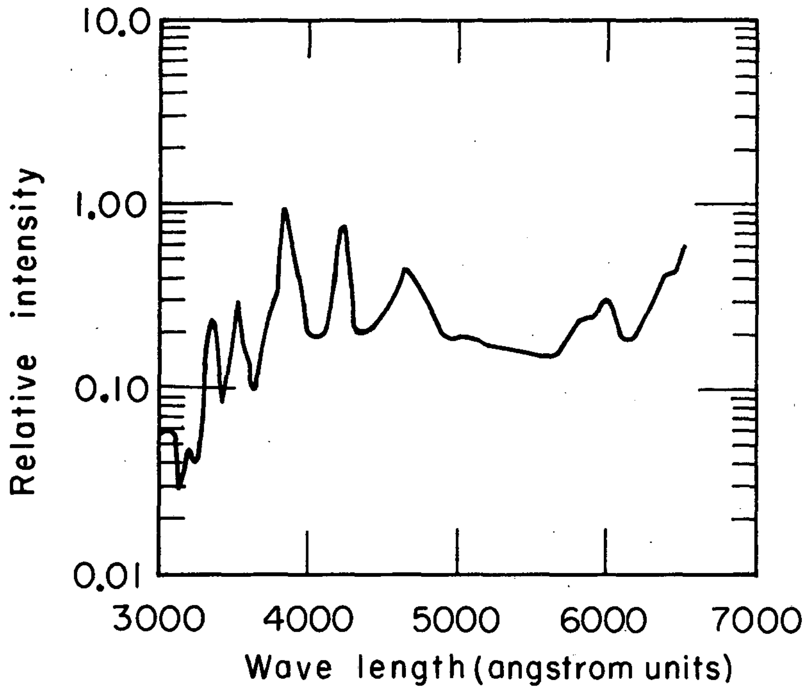

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Fig. 11. Corona lamp spectrum.

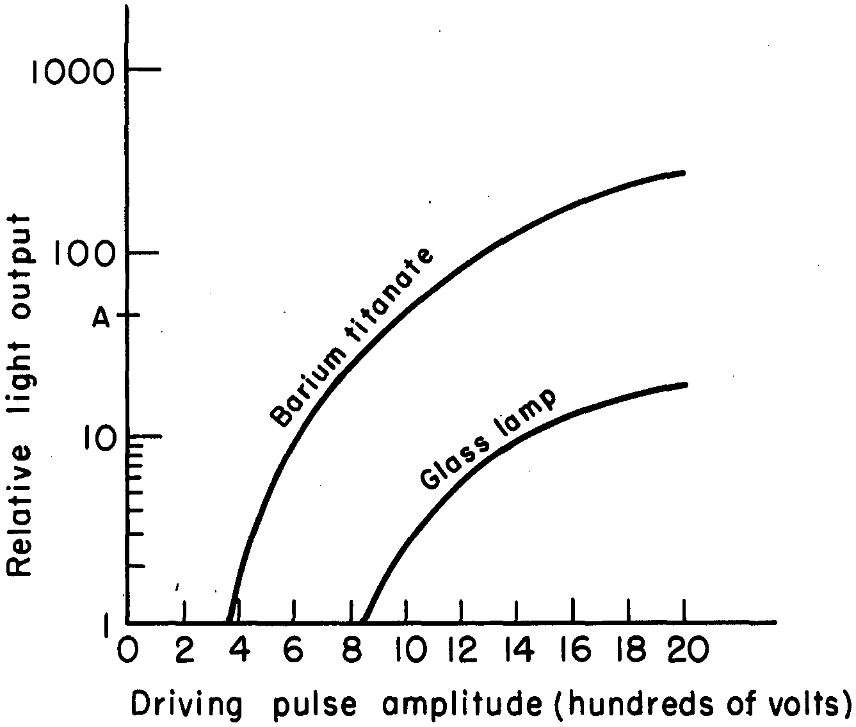

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Fig. 12. Light intensity as a function of pulse voltage. Point A represents 5000 photoelectrons, 6 1/2 in. from a 2-in. phototube.

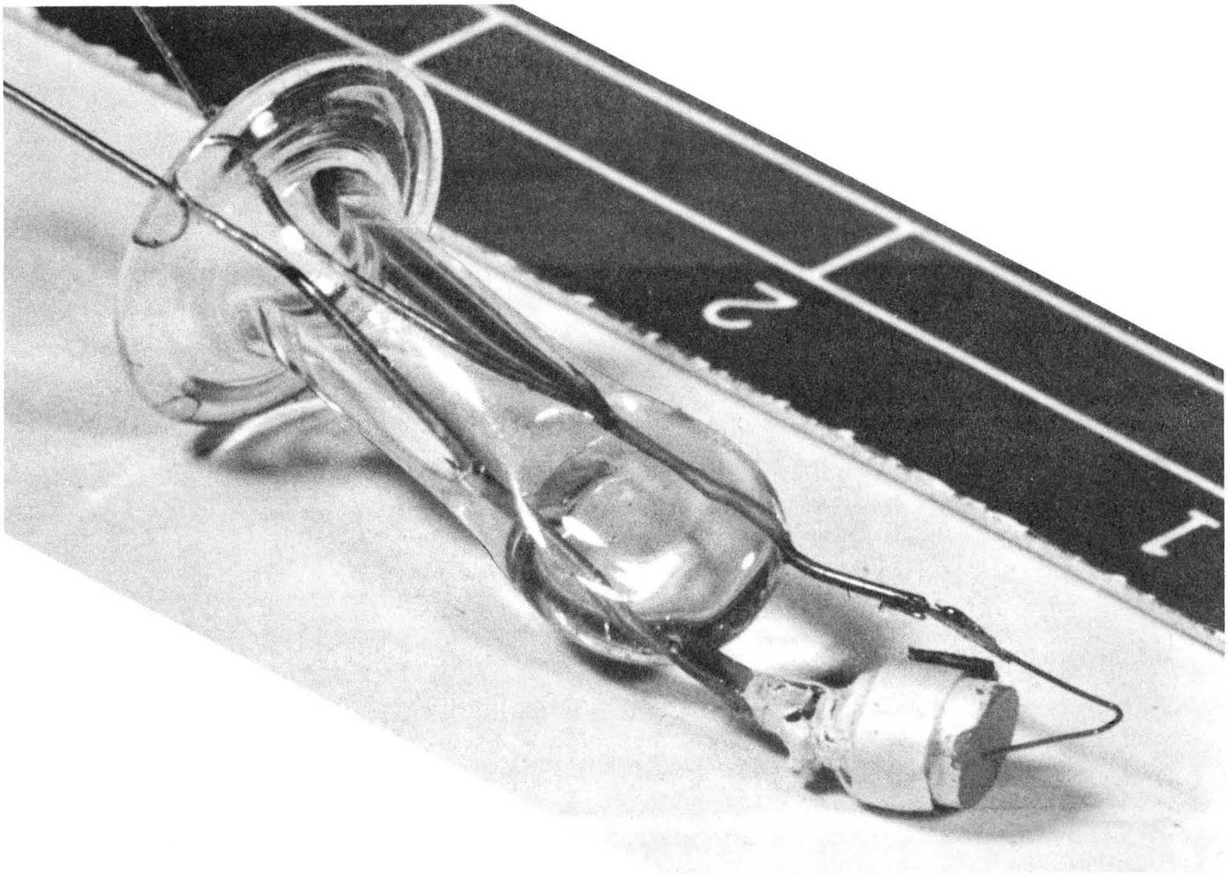

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Fig. 13. A barium titanate lamp without the outer glass envelope. The scale is graduated in centimeters.

OPTICAL ATTENUATOR

A variable optical attenuator is shown attached to one of the Corona lamps in Fig. 9. It provides an adjustment of the light amplitude without disturbing any of the electrical settings.

An adjusting ring moves an inner Polaroid film with respect to the outer Polaroid film and lamp, with stops at maximum and minimum attenuation. Indexing lines are spaced to give attenuation steps of two, up to an attenuation factor of 64. The maximum attenuation is greater than 100 times minimum attenuation.

Mechanical strains in the polarizing films must be avoided, as they give rise to double refraction. Satisfactory results have been achieved with a glue of Epoxy resin #820 plus an air-dry DTA catalyst.[*] Fixed optical attenuators have been used, as well as electrical attenuators such as the General Radio No. 874-G3-- which, however, should not be used at the 3-kv level, though it may be used at the lamp.

Circuit schematic diagrams, fabrication drawings, and accessory drawings are available. They are listed on Lawrence Radiation Laboratory Drawing No. 4X1091.

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[*] Diethylenetriamine from Shell Chemical Company.

ACKNOWLEDGMENT

We wish to thank Mr. Bob Reynolds for the mechanical design of the lamp holders and the optical attenuators, Mr. Harry Powell for the lamp construction, and Mr. Lee Wagner and Dr. Yahia El Hakim, who obtained the data for Figs. 12 and 11, respectively.

This work was done under the auspices of the U.S. Atomic Energy Commission.