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Ultraviolet Lamp for the Generation of Intense, Constant-Shape Pulses in the Subnanosecond Region

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A commonly available mercury contact relay is modified to make a uv lamp which yields a spark with approximately 100 times the intensity of the original relay and with constant characteristic risetime of 0.4 nsec, decay time of 0.55 nsec, and half-width of 0.5 nsec. The lamp can be used not only for fluorescence decay-time studies, but also for electrical applications in the subnanosecond region. It has been operated in the range 3 to 50 000 pulses per second.

1. INTRODUCTION

EXPERIMENTAL studies of fluorescence decay times of the order of 1 nsec require use of extremely short uv pulses for excitation of the system. Heretofore, lamps providing sufficiently short pulses for this purpose were neither sufficiently reproducible nor sufficiently intense for the intended application.[1-3]

Although it is well known that mercury contact relays do exhibit a small uv spark of approximately the required pulse character and are, at the same time, adequately long-lived,[4] their application as pulsed light sources is limited by two shortcomings: (1) because they operate at low voltage (~1000 V max), their light outputs are unsatisfactorily low; (2) after the main pulse they exhibit secondary pulses[1] which are particularly disturbing at high repetition rates. Consideration of the potentialities of the mercury relay device indicates that it is the switch-like operation of the vibrating reed which is responsible for such deficiencies and which limits its utilization as a light source. The vibrating electrode is associated with an ill-defined and varying electrode geometry which, in turn, is reflected in field and capacitance variations that lead to observable secondary discharges. If an attempt is made to improve light output by application of higher voltage, the after-pulse effect is even more increased.

The preceding explanation of the limitations on usage of the relay as a pulsed light source is supported by experiments (not herein described) in which mercury contact relays were operated with fixed electrode separation up to 0.7 mm in length. Depending on the gap width establishable in commercially available relays,[5] firing voltages up to 10 kV were obtained without secondary pulses. In these relays only one electrode actually dips into the mercury, but repeated physical contact between the electrodes wets both of them. However, we have found that when the relay is used as a lamp with electrodes in fixed position, both the electrodes remain coated with mercury during operation despite the fact that only one is actually immersed. Speculation as to the precise mechanism of this phenomenon is unnecessary here. The totality of the results suggested the design of a lamp embodying the merits of a mercury relay but devoid of its shortcomings.

2. THE LAMP

Figure 1 shows a design of a lamp which has been found to possess the required operating characteristics. Unlike the commerically available relay (containing several contacts and three electrodes one of which vibrates to make electrical contact) this lamp has only two electrodes, which, as in the relay, are made of a nickel-iron alloy. The spring, or lower, electrode is held in a constant position relative to the fixed electrode by means of a permanent magnet.[6] In a typical lamp the gap length is thus fixed at ~0.7 mm. The reduction in number and size of electrical elements of the lamp contributes to a reduction of stray capacitance, which must be held to a minimum. The lamp, which contains a

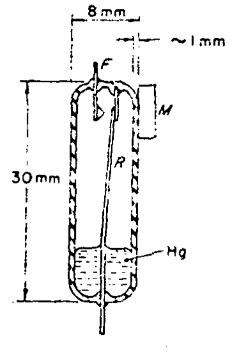

FIG. 1. Flash lamp, F, fixed electrode; R, reed electrode, held in fixed position by permanent magnet; M, permanent magnet.

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1 Q. A. Kerns, F. A. Kirsten, and G. C. Cox, UCRL-8227 (1958).

2 Y. Koechlin, Thesis, Faculté des Sciences, Université de Paris (1961).

3 M. Burton, P. K. Ludwig, and J. D'Alessio, International Conference on Luminescence, Torun, Poland, September 1963.

4 The long life of this type of relay is attributed to the mercury coating on the electrodes. H. C. Harrison, U. S. Patent 2302546, 17 November 1942.

5 The Adams and Westlake Company (Elkhart, Indiana) mercury wet contact relays.

6 Unlike the arrangement for the relay, no driving coil is employed.

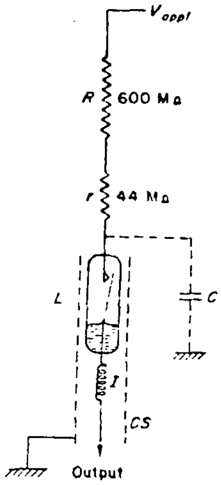

FIG. 2. The lamp circuit. C, stray capacitance; CS, coaxial shielding, I, compensating inductance; L, lamp; R and r, charging resistors; V_{appl}, applied voltage.

droplet of mercury in the bottom part, is filled with hydrogen; a suitable pressure currently employed is 18 atm. Except as otherwise indicated here and in Sec. 4, the components correspond in material and preparation to those in the commercial mercury relay. An important feature of this lamp, worthy of special note, is that the small spark light source makes for optical convenience.

3. THE CIRCUIT

Figure 2 includes a rather conventional circuitry for the free-running mode of operation. At the constant capacitance of the system, repetition rate is determined by the values of R and V_{appl}. The lamp has been operated at 3 to 50 000 pulses per second. To obtain a desirable pulse shape, stray capacitance of the lamp and associated electrical components must be reduced to a minimum value. For example, to reduce troublesome capacitance of the high voltage leads, it is necessary to mount the small size 44-MΩ resistor as close to the lamp as possible. As nearly as can be achieved, all conductor elements including the lamp, except for a small aperture for emergence of the light, are coaxially arranged. The small adjustable inductance in the output lead close to the lamp suppresses distortions at the trailing edge of the pulse.

The electrical pulses from the lamp were observed with an Edgerton model 707 traveling-wave oscilloscope (risetime 0.2 nsec) or a Hewlett-Packard sampling oscilloscope type 185A (risetime 0.3 nsec). Observation of the light pulse was by a modification of the Dreeskamp-Burton optical sampling technique.[7-9] The time resolution of this sampling equipment has now been established to be less than 0.1 nsec.

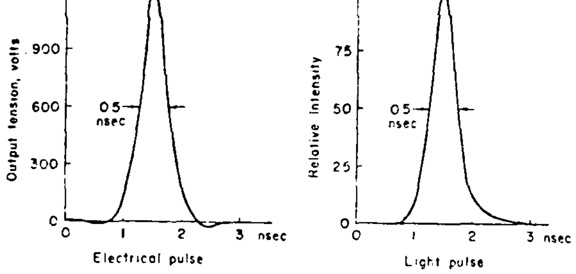

FIG. 3. Typical pulses delivered by the lamp.

4. RESULTS

Figure 3 shows the shape of electrical and light pulses typical of the lamp and circuitry described. By use of the stray capacitance of the assembly alone, pulses with characteristic risetime of 0.4 nsec, decay time of 0.55 nsec, and half-width of 0.5 nsec were obtained.[10] Calculations from the circuitry and from repeatedly plotted curves indicate that, for a fixed setting, the observable maximum of the curve is reproducible within 1-2%. Very importantly, these characteristics are essentially unaffected over a voltage range of 1 to 10 kV firing tension; i.e., they are practically independent of the electrode spacing over this voltage range.

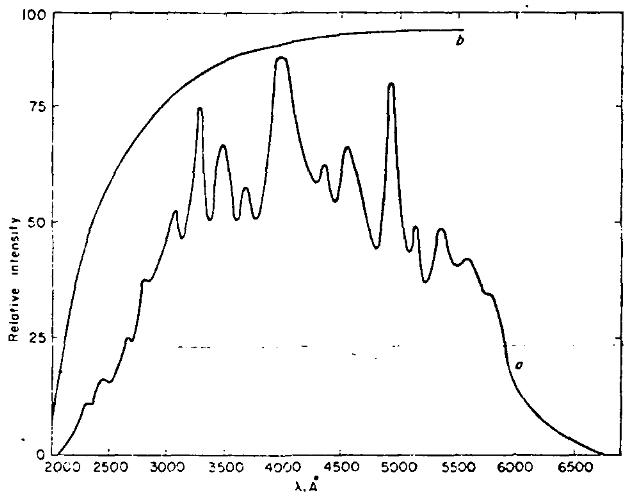

FIG. 4. (a) Spectrum of the flash lamp with uv glass, (b) transmittance curve of 9741 Pyrex glass used in the lamp.

According to Kerns, Kirsten, and Cox[1] the light output in mercury-relay type lamps is roughly proportional to the square of the firing voltage for tensions exceeding 2000 V. On this basis the light intensity for the lamps described may be estimated to be approximately 100 times that of the mercury-relay lamp; i.e., $\sim 6\times 10^5$ photons per pulse in a solid angle of 0.005 sr, and about 30% higher for a uv transmitting glass.[11] A typical emission spectrum of a lamp

[7] H. Dreeskamp and M. Burton, Phys. Rev. Letters 2, 45 (1959).

[8] H. Dreeskamp, A. K. Ghosh, and M. Burton, Rev. Sci. Instr. 32, 304 (1961).

[9] J. T. D'Alessio, P. K. Ludwig, and M. Burton (unpublished).

[10] Risetime corresponds to a change from 10 to 90% full intensity and decay time to a decrease over the same range.

[11] Some appreciation of this intensity is given by the fact that a lamp operating at one pulse per second, at half-width 0.5 nsec, can be seen in a well-lighted room with the unaided eye.

made from Corning UV 9741 Pyrex glass is shown in Fig. 4. The transmittance curve of the glass is included in the figure.

The lamp described not only represents an improved tool for the study of fluorescence decay times, it also provides an excellent means for generating high voltage electrical pulses in the subnanosecond region. With the present manner of operation, electrical pulses of 0.5 nsec half-width at about 1200 V have been obtained across a 50-Ω resistor (see Fig. 3).

Based on the observation that the time characteristics of the pulse are not significantly affected by the firing voltage in the range from 1000 to 10 000 V, an objective of current work is to obtain additional increase of the light output (i.e., of the pulse height) by increase of the firing tension.

ACKNOWLEDGMENT

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