

- 91 G. I. Belinskaya, M. S. Guskova (Russia), *Short Exposure Time Effect of Photographic Image Sharpness and Contrast Transfer Functions of Films*
- 92 T. H. Healey, H. M. Owren (United States), *Quantitative Data Acquisition with Image Converter Camera Systems*
- 93 P. R. Lord (United Kingdom), *High-Speed Photography and Photo-Elasticity*
- 94 J. R. Crosnier (France), *Etudes de couples thermoélectriques soumis a des ondes de choc en milieu métallique*
- 95 D. Ebeling (Germany), *Monochromatische High-Speed Photographie mit modulierten Impuls-Lasern*

ADDITIONAL PAPERS PRESENTED

96 Cancelled

- 97 H. Tannert (United States), *A 16mm High-Speed Intermittent Camera—the "Monitor" 600 Camera System*
- 98 A. S. Dubovik, V. V. Garnov, N. M. Sitsinskaya (Russia), *High-Speed Image Dissector Twin-Disk Camera*
- 99 A. S. Dubovik, V. V. Garnov, N. M. Sitsinskaya (Russia), *Stereoscopic Photography with High-Speed Image Dissector Cameras*
- 100 G. I. Mishin, U. A. Dunayev, V. G. Maslennikov, M. P. Sistchikova, G. K. Tumakayev (Russia), *Application of Optical Research Methods at Ballistic Ranges and in Shock Tubes*
- R. S. Dennen, A. V. Appel, E. P. Stridde, J. Gershon (United States), *High-Speed Schlieren-Cine Photography of Electrically Generated Imploding Shock Waves*
- T. Rogers (United Kingdom), *The Control and Synchronisation of a Rotating Mirror Camera*

ADDENDUM IV — Films Shown at the Congress

- The Priceless Laboratory; Eclipse of the Quiet Sun*, Douglas Aircraft Co., Marketing Communications, Film Production, Santa Monica, Calif. 94720.
- Food, the Color of Life*, Reid H. Ray Film Industries, Inc., 2269 Ford Parkway, St. Paul, Minn. 55116.
- Fish, Moon and Tides—The Grunion Story*, Academy Films, 748 N. Seward St., Hollywood, Calif. 90038.
- To Catch a Porpoise*, Burton Clark, General Manager, Miami Aquarium, Rickenbacker Causeway, Miami, Fla. 33149.

- Flow Visualization; Surface Tension in Fluid Mechanics*, Educational Services, Inc., 47 Galen St., Watertown 72, Mass.
- Molecular Spectroscopy*, David W. Ridgway, Director of Film Activities, Chemical Education Material Study, Lawrence Hall of Science, University of California, Berkeley, Calif. 94720.
- Step Into Space; U.S. Manned Lunar Expedition; The Four Days of Gemini IV*, Andrew M. Sea, Chief, Audio Visual Services, Public Affairs Office, AP2, NASA Manned Spacecraft Center, Houston, Texas 77058.
- The Dolphins That Joined the Navy*, Produced by the U.S. Navy.

# Summaries of Papers on Several Light Sources and a Framing Drum Spectrograph

By FRANCIS D. HARRINGTON

THE general lecture of Professor H. E. Edgerton, four papers on light sources and one paper on a framing drum spectrograph are reported.\* The authors were kind enough to send transcripts of their papers together with appropriate illustrations; the latter are incorporated herein. Appreciation and thanks are expressed to these authors for their generosity. The following is this reporter's interpretation of the assignment.

In his general lecture on "Applications of Xenon Flash" Professor H. E. Edgerton† stated "the object of the paper is to review briefly the theory of the xenon flashlamp and to help those who have applications." It is impossible in this even briefer review to do justice to the fine presentation and the reader will appreciate this when the full paper is published in the *Proceedings of the 7th*

Congress. A sizable bibliography is contained in the paper.

The classical theory of electrical breakdown, the inconsistencies occurring in self-breakdown, and the merits of external triggering of xenon lamps were discussed. Figure 1 shows the phenomenon which occurs in the initial phase in the development of the discharge when external triggering is used. Figure 2 sketches the physical setup and the type of oscilloscope traces derived from this type of triggering. The "kink" observed in the oscilloscope traces is believed to be associated with the onset of ionization. The development of the xenon arc with respect to time was illustrated by rapid framing photography.

Major characteristics of these lamps, such as, arc resistance, flashlamp life and spectral output and efficiencies from 0.35 to 1.1  $\mu$  were discussed.

Applications of xenon lamp, briefly reported here, were described in some detail for variable stroboscopic motion study photography, single flash for normal photography, motion-picture and multiflash photography, underwater photography, flashing beacons for aircraft and satellites as well as lighthouses, laser optical pumps, and flash photography used in medical research.

W. Thorwart, J. F. Suarez and H. G. Patzke (1) described a multi-sequenced

light source in an improved compact design of a Cranz-Schardin arrangement. It consists of eight triggered spark gaps spaced 9 mm apart in a 63-mm high vertical row, the arrangement placed close to the side of the camera head fixture. The parallax inherent in the original arrangement of Cranz-Schardin is hardly noticeable in this design because of the compact array of gaps. Each spark gap is triggered from a controlled third electrode onto the main electrode of the gap. A single lens is used for all eight gaps and eight adjustable prism systems in the camera head orient the frames in a still camera focal plane. The framing rate for a transient optical event is at a rate up to 10<sup>6</sup> frames/s. Figure 3 illustrates the arrangement of the spark gaps and

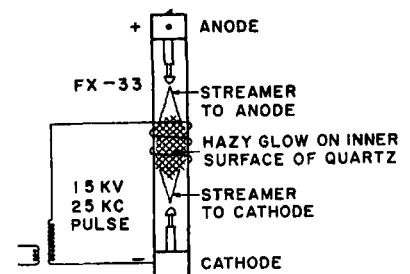


Fig. 1. The initial phase in discharge development when external triggering is used.

A paper to be presented during the Society's 99th Conference in Washington, D.C., May 1-6, 1966, by Francis D. Harrington, Radiometry Branch, Optical Physics Div., U.S. Naval Research Laboratory, Washington, D.C. 20390 (This paper was received on March 8, 1966.)

\* Numbers in parentheses refer to the papers' numbers in the Congress Program as listed on pp. 353-355. The papers will appear in the *Proceedings of the Seventh International Congress on High-Speed Photography*, to be published by Verlag Dr. Othmar Helwich, D-61 Darmstadt, Hoffmannstr. 59, Germany.

† General Lecture, Session 1, Congress Program, p. 353.

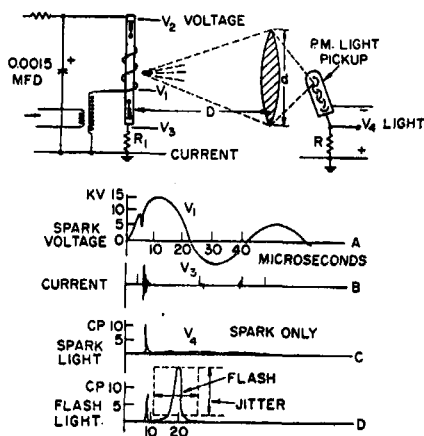


Fig. 2. Physical set-up and types of oscilloscope traces derived from external triggering.

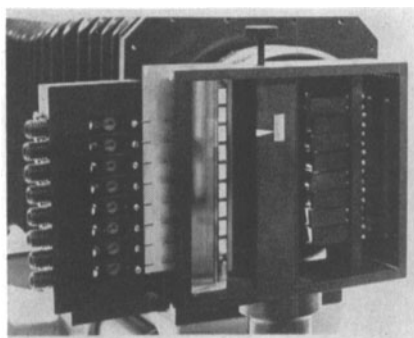


Fig. 3. Arrangement of spark gaps and camera head for multi-sequenced light source.

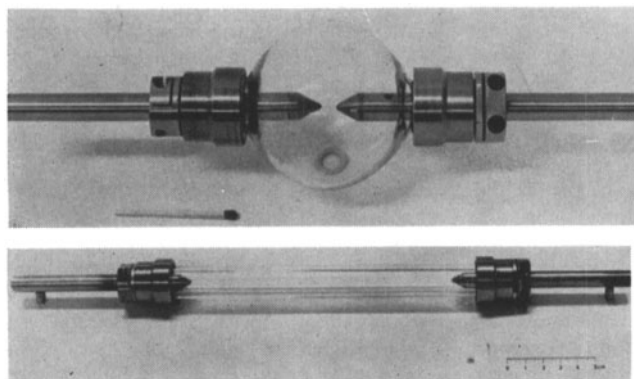


Fig. 4. A short arc spherical design which was developed in two types: one for a thermal load of 400 W; the other for 2,000 W.

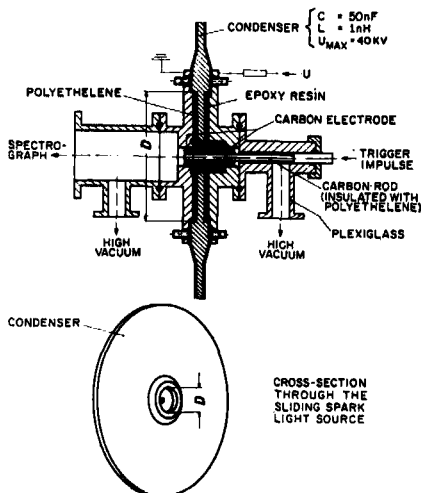


Fig. 6. The condenser and light source formed in a single unit in the high-intensity, low inductive sliding spark light source.

The lamp does not have a triggering electrode but is operated as a diode. Triggering is accomplished by a new method which allows a steep low-energy pulse to effect the sparkover which in turn is quickly followed by the main discharge. The latter builds up to tens of kiloamperes. This circuit allows for increased stability and life of the lamp, achievement of short flash pulses and lamp operation at a lower voltage than that normally required for such electrode spacings.

camera head which is located in front of the camera lens. The energy per spark is 10 J for a half width duration of 150 ns. The time interval between individual spark discharge is equal and can be varied from 1 s to 1  $\mu$ s. The spark gaps are adjustable for even spark-over in the 4-6 kV range. The light source is useful for schlieren, shadow or counterlight photography.

Another arrangement places the spark-gaps in a horizontal row in confocal succession between lenses of an optical train which causes them to cascade in sequence. This system is parallax free and useful with a synchronized rotating mirror camera or an image-converter camera. The light source is suitable for both front and back lighting requirements.

A paper by F. Früngel and G. Röder (2) described several types of demountable high pressure discharge lamps of both short and long arc design. These have the advantage of easy cleaning when the Pyrex or quartz envelopes have been blackened by electrode burn off. The electrodes have a sintered alloy of tungsten with 15% thorium and have shown the best burn resistance to strong discharges. The electrodes are adjustable and one electrode is vented to provide a means of passage into the tube. A special device is attached to this lead in order to fill and seal off the tube at a maximum pressure of 4 atm of the desired gas.

Figure 4 shows a short arc spherical design which has been developed in two types, one for thermal load of 400 W and the other for 2000 W.

Figure 5 is a long arc capillary tube of the same basic design and useful for high-intensity flashes of up to 10,000 J. Also exhibited was a water cooled capillary for heavy loading. These flash lamps are applicable for extended use in high-speed photography and as laser pumps.

P. Bogen and H. Conrads (4) discussed a low inductive sliding spark light source of high intensity which was triggered in a vacuum. The discharge produced an intense spectrum in the visible and vacuum ultraviolet regions. In the soft x-ray region an intense radiation of CV and CVI lines appeared. The maximum intensity in the visible is said by the authors to have approximated a blackbody of 450,000°K. The half width of the pulse at maximum intensity was about 70 ns with a variation in discharge of less than  $\pm 5$  ns.

The condenser and light source are formed into one unit as shown in Figure 6. The carbon electrode holders are separated by a circular insulating flange which prevents radial discharge. The internal carbon electrodes (spaced by a polyethylene insulator) all have a common bore-hole or channel which can be varied from 0.5 to 1.5 mm. Spectroscopic observations of the discharge channels are made end on from one side of the unit. A polyethylene insulated carbon rod is guided in the other side and used as a coaxial ignition electrode.

The pulse duration of the strongly damped discharge is approximately 0.2  $\mu$ s at 4340Å. The maximum intensity of the pulse is reproducible to about  $\pm 4\%$ , and the duration of pulse is accurate to less than 10 ns.

When the discharge was operated at 15 kV, the source compared to a blackbody of 275,000°K, whereas, for 35 kV it approximated a blackbody of 450,000°K. The parameters of the plasma, such as temperature, density and optical thickness were theoretically discussed.

H. E. Edgerton and V. E. Mac-Roberts (5) presented a circuit designed to operate a durable multiflash strobe light source for a type of motion study photography which requires a considerable amount of light in repetitive flashes. Figure 7 is a multiflash photograph thus obtained with the desired lighting and a pulse frequency of 120 flashes/s.

The circuit produces strobe pulses of 120, 60, 30, etc., per second which are in phase with the 60-cycle line frequency. Provisions were made for the discharge to occur at a determined time in the cycle when the voltage is decreasing to, or nearly zero. This partially eliminates the arc holdover and allows the lamp to deionize between pulses.

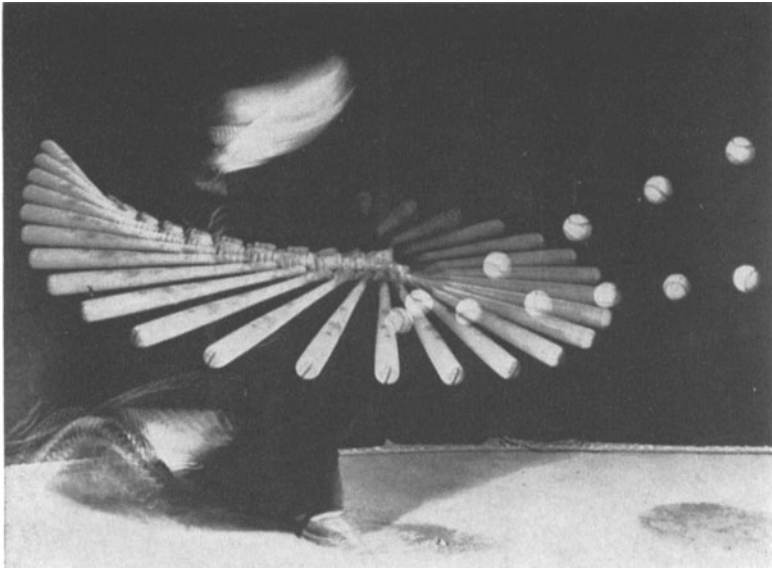


Fig. 7. A multiframe photograph obtained using a multiframe strobe light with a pulse frequency of 120 flashes/s.

For those interested in time-resolved spectroscopy of transient or expanding light sources, a paper presented by W. A. Waller (12) on a new type of framing drum spectrograph should be of some interest. The spectrograph is continuously accessible to the optical event without synchronization. It possesses an additional feature of spatial resolution which is provided by an image trans-

former consisting of an array of 200  $\mu$  diameter coated quartz fibers. The fibers are arranged in a  $10 \times 10$  fiber square (2 mm  $\times$  2 mm) as the entrance aperture of the transformer upon which the light source is focused. In turn, the 100 fibers are arranged in a known order to form a single vertical column of 20-mm high. The end of each fiber acts as a pinhole "slit" which gives rise to an

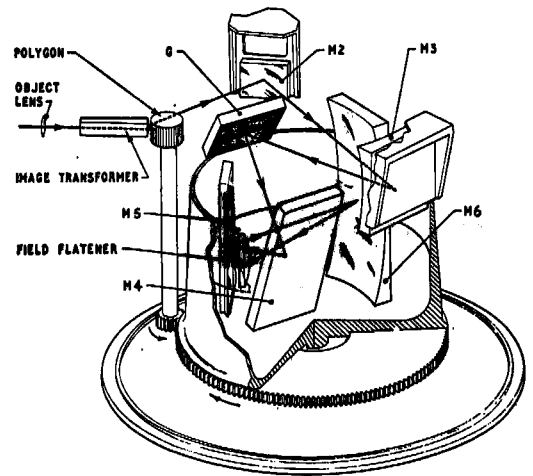


Fig. 8. Optical system of framing spectrograph.

independent spectrum. If all fibers are illuminated by the light source, there will be 100 spectra per frame. A total of 900 frames are recorded in 9 ms at rate of 100,000 frames/s. A rotating polygon positioned in front of the vertical column of fiber ends is geared to the rotating drum of the spectrograph. The polygon contains 90 facet mirrors which provide the framing interval. Figure 8 shows the  $f/3$  optical system of the spectrograph. The spectrograph has a wavelength coverage of 3000 to 9000 $\text{\AA}$ , wavelength resolution of 5 $\text{\AA}$  and a reciprocal linear dispersion of 50 $\text{\AA}/\text{mm}$ .

# Hypervelocity Impact and the Seventh International Congress on High-Speed Photography

By P. L. CLEMENS

Edit. Note: Papers 41, 42, 43 and 44 from the Seventh International Congress on High-Speed Photography are discussed by P. L. Clemens in relation to the hypervelocity impact aspects, and by J. P. Barbour for the x-ray techniques. In addition, a brief discussion of paper 44 is presented by B. E. Drimmer in his report on shock waves and detonation.

WITH THE ADVENT OF space flight and advanced missilery, studies of the effects of hypervelocity impact have come to be of increasing importance.\* Meteoroid collisions with the hulls of spacecraft and warhead encounters with defensive devices may be expected to occur at velocities far exceeding the speed of sound in the structural materials which are involved. (Christman, Gehring, and others have prepared a comprehensive

A paper to be presented during the Society's 99th Conference in Washington, D.C., May 1-6, 1966, by P. L. Clemens, Aeroballistics Branch, Von Karman Gas Dynamics Facility, ARO, Inc., Arnold Air Force Station, Tenn. (This paper was received on March 8, 1966.)

\*Numbers in parentheses refer to the papers' numbers in the Congress Program as listed on pp. 353-355. The papers will appear in the *Proceedings of the Seventh International Congress on High-Speed Photography*, to be published by Verlag Dr. Othmar Helwich, D-61, Darmstadt, Hoffmannstr. 59, Germany.

discussion of the basic phenomena of hypervelocity impact.†) At these velocities, analytical methods are often in conflict and of little value in predicting damage effects. Empirical methods must be used to produce data describing the worth of projectile and shielding designs, providing guidance toward design improvements, and furthering understanding of the basic mechanism of hypervelocity impact. In laboratory test work of this kind, projectiles are hurled against specimen targets which are often contained within evacuated chambers. The projectiles are customarily launched either from now-classical, two-stage

†D. R. Christman, J. W. Gehring, C. J. Maiden and A. B. Wenzel, "Study of the phenomena of hypervelocity impact," *General Motors Defense Research Laboratories TR-63-216*, June 1963.

guns‡ or by shaped charge devices. In either case, the gathering of definitive data during the testing relies heavily upon high-speed photography and imposes a challenging set of requirements. The more demanding of these requirements stem chiefly from three characteristics of hypervelocity impact:

(1) Projectile velocities as great as 33,000 ft/s (two-stage guns) or 52,000 ft/s (shaped charge launchers) are encountered. Thus, photographic methods must provide submicrosecond exposure durations to resolve the behavior of small particles effectively.

(2) Clouds of particles are ejected during impact crater formation. These obscure from view many of the effects which occur during critical phases of the

‡W. D. Crozier and W. Hume, "High velocity light gas gun," *Jour. of Applied Physics*, 28: Aug. 1957.