High-Intensity, Fractional-Microsecond Light Sources

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High-intensity light sources have been developed for military applications in optical ranging, communications and navigation. These sources provide a small-area electric spark with a peak brightness of approximately 50 million candles/cm², and a duration of less than 0.5 μsec. These sparks may be operated at resonant frequencies or triggered accurately by triggering electrodes. Normal frequencies of operation up to several kilocycles are possible under certain conditions. Spectrographic measurements indicate an effective blackbody temperature of the order of 30,000 K. Developmental work has included experiments with spark atmospheres of various compositions and pressures.

THE PRESENT discussion of the Farrand pulsed light source is based on the experience of a large number of staff members who have been engaged in its development. The work on lamp development was initiated under U.S. Navy, Bureau of Naval Weapons auspices. The work has had the support of various members of the Defense Department including the Air Force and Army, in addition to the Cornell Aeronautical Laboratory and the Martin Co.

Our primary objective has been the development of a source of light of maximum brightness, in small volume, with the shortest possible rise time. The emphasis on small volume of the radiator and short rise time was required by the basic system design of our pulsed light ranging equipment.

Our work has lead to the production of two main types of pulsed light sources. They are sparks in air or high-pressure gas. The condenser which stores the energy to feed the spark is an integral part of the lamp structure. The principal design effort has gone into the mechanical and electrical design of the condenser and structure which mounts the electrodes. A typical pulsed light source is illustrated in Fig. 1.

Characteristics

The latest model, Model 9, source is a tungsten electrode spark gap in air of 0.030-in. gap length. The diameters of the tips are 0.030 in. A metal ribbed cage surrounds the gap to provide the best approximation to a concentric transmission line. The condenser which feeds the gap is specially wound with the result that the inductance of the condenser itself is less than 10^{-10} h. The measured inductance of the complete electrode and condenser structure is 2×10^{-9} h. The capacitance is 0.8 μf.

The pulse shape of the light intensity shows a rise time of 0.12 μsec and a pulse length of 0.375 μsec. The energy input per pulse is 5.0 j/flash. The peak electrical current in the gap is 35,000 amp. The peak power radiated in the visible and ultraviolet regions of the spectrum is 150,000 w.

It is noteworthy that the present structure is not critically damped. The resonant frequency of the structure is 2 megacycles/sec. In the Model 8 lamp the output light pulse shows modulation of the light output at 10 megacycles/sec of 10% on the decaying slope (Fig. 2).

The light output characteristics are as follows. The maximum brightness is 60×10^6 candles/cm². The peak horizontal candlepower is 1.3×10^6. This leads to a total output per pulse of 0.34 horizontal candlepower sec.

The angular distribution is essentially spherical except for the shadows of the cage ribs and the electrodes. The total solid angle illuminated is approximately 3π steradians.

The spectral distribution of the lamp is shown in Fig. 3. The color temperature and brightness temperature determined by the best fit to the blackbody curve is 30,000 K. This is true for wavelengths out to 12 microns.

Operation

The source radiates a continuous spectrum for the first 0.1 to 0.3 μsec. During this time the source is opaque to its own radiation. The normal spectrogram shows broadened lines superimposed on a continuous spectrum background. The spectral distribution curves after the first microsecond exhibit different pulse lengths in time for different wavelengths throughout the spectrum. This variability leads to the necessity of determining the effective photographic exposure directly.

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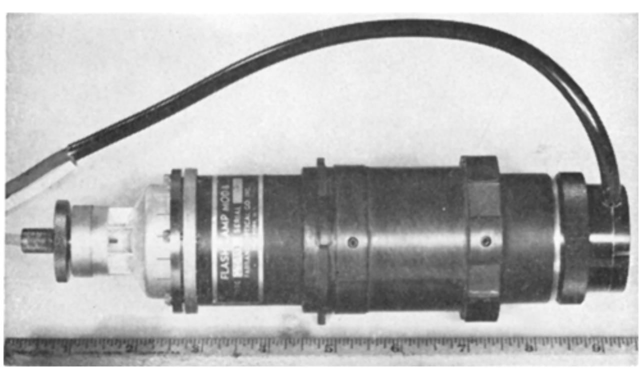

Fig. 1. A typical pulsed light source.

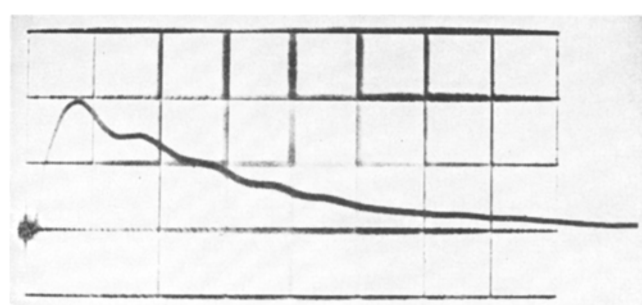

Fig. 2. The light output of the Model 8 light source. Time scale: 10^{-7} sec/division.

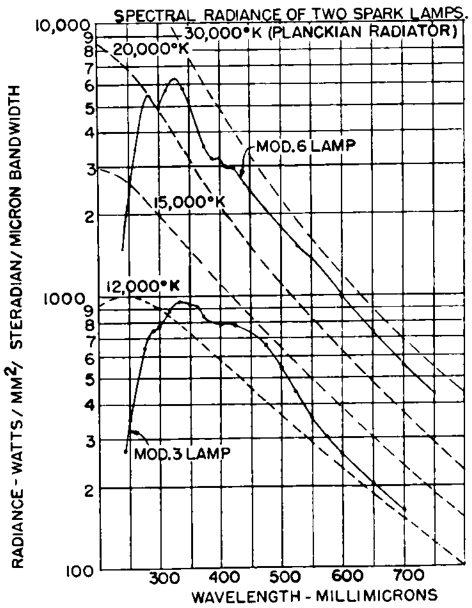

Fig. 3. Spectral radiance of blackbodies and of two spark lamps.

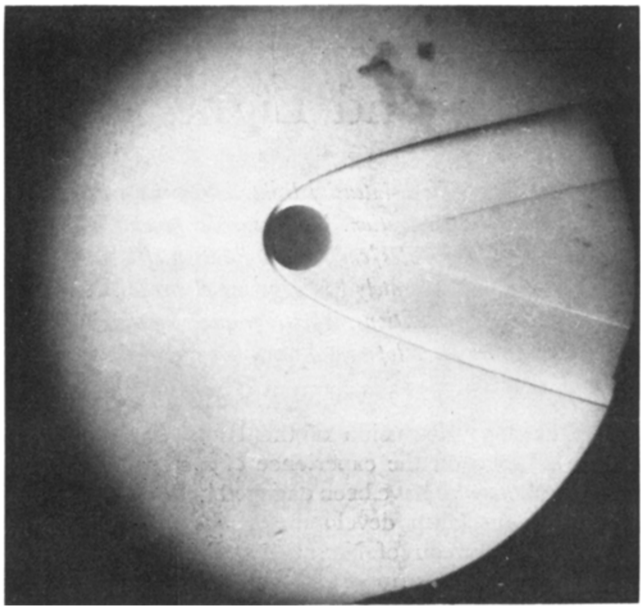

Fig. 4. Photograph of 0.5-in. diameter sphere projected at 7700 ft/sec using a pulsed light source. (Official U.S. Navy Photograph)

The effective photographic exposure time determined by two independent methods is less than 0.2 μsec. The effective photographic exposure time determined by the amount of image blur of pellets traveling at a speed of 7700 ft/sec is less than 0.2 μsec. This is shown by Fig. 4. For a photographic exposure time of 0.2 μsec, the photographically determined output is 1 horizontal candlepower sec.

It is possible to obtain photographs by means of reflected light photography of large areas using the pulsed light source. For example, it is possible to obtain single flash exposures of 0.2-μsec duration with the source illuminating an area of 10 by 10 ft at a distance of 20 ft when an *f*/0.87 Super Farron lens is used.

If the high-speed photography problem requires a relatively small area throughout which photographs may be obtained, then it is most efficient to employ a mirror condenser system to illuminate the subject area. For example, using the Farrand pulsed light source and a 24-in. diameter parabolic mirror, it is possible to obtain single flash photographs by reflected light at 0.2-μsec exposure with an *f*/30 lens.

The Farrand pulsed light source is ideally suited for use with gated image tubes for extremely short time photography. The pulsed light source has been used with a gated image orthicon for 0.25-μsec exposures of natural terrain in daylight. For example, the beam candlepower of the searchlight used in this application for illuminating natural terrain was 1.8×10^{11}. Using this source, it then becomes theoretically possible to obtain shadowgraph exposures in a 100-line picture for a 10^{-10}-sec exposure time.