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A Capillary Pulse Light Source Giving 40,000 K Blackbody Radiation

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A high-temperature pulse light source has been developed for use in high-speed photography, high-temperature pyrometry, plasma spectroscopy, etc. Like a standard source it dependably maintains a constant radiation brightness notwithstanding the amount of use and storage time.

The radiant source is provided by an electrical discharge with rectangular-shaped light-pulse pattern in a capillary with both ends open. The capillary is made of a shatter-proof plastic. The source radiates a uniform continuous spectrum in the 1900 to 7000 A range, with line emission and absorption contributing not more than 1%. The absorption ability of the discharge plasma in the visible and ultraviolet is close to unity because of the high pressure (~500 atm) created in the capillary simultaneously with the discharge process. Photoelectric measurements show that, in the 2500 to 6000 A range, the radiation of the pulse source corresponds to that of an absolutely black body at 39,000 ± 2000 K.

HIGH-SPEED photography, high-temperature pyrometry, plasma spectroscopy and some other branches of research require an intense pulse light source. The radiation as a function of time should be emitted as a rectangular-shaped pulse. Such a source must be adequate for any work for which a standard ribbon incandescent lamp is suitable.

In the present work, a powerful pulse discharge is used in a channel of restricted diameter, to provide such a source. The radiation is produced in a capillary having both ends open, by a discharge with a current density of about 3×10^5 amps/cm^2. The capillary is made from Textolite, Plexiglas, or a fluorinated shatterproof plastic. In practice the radiation from the open ends of the capillary is used, along the direction of its axis.

The capillary length is 10 mm and the initial diameter is 2 mm. The discharge is fed from an artificial LC-line which produces individual rectangular current pulses of 10,000 amp. The pulse duration is adjustable from 100 to 400 μsec.

The current and voltage oscillographic patterns of the discharge are similar in form; and, consequently, this discharge has an ascending volt-ampere characteristic. Such a characteristic permits a good matching of the resistance of the discharge with the characteristic impedance of the line without requiring an additional load resistance.

Direct measurements under stationary conditions show that the pressure in the capillary during the discharge reaches 450 to 500 atm, and the voltage gradient along the column is about 1000 v/cm. The pressure surge is due to the fact that the existing current densities cause heavy thermal destruction of the material of the inner capillary wall. This is followed by the outflow of jets of the plasma from the open capillary ends. The gas of the discharge plasma is formed entirely from material of the wall of the capillary.

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In the 1900 to 7000 A range which was investigated, the source radiates a uniform continuous spectrum with a few absorption and emission lines belonging to elements of the materials that compose the electrodes and the capillary wall. The noncontinuous emission and absorption spectra originate in the plasma jet flowing out of the capillary, and constitute less than 1% of the total radiation of the source.

An oscillographic investigation of light from the source and the high-speed scanning of the spectrum showed that the light pulse has a rectangular pattern that is independent of the wavelength. The maximum source brightness is reproducible within 2 to 4% when the initial diameter of the discharge channel, the discharge current, and the capillary length are calibrated.

The measurement of the brightness distribution in the cross section of the capillary showed that, in the axial zone, there exists a uniformly bright region of 1-mm diameter in which the brightness variation does not exceed ±2%. The radiation brightness diminishes toward the capillary wall.

The absorptive ability of the discharge plasma in the visible and ultraviolet ranges of the spectrum is very close to unity and consequently its radiation may be expected to be very close to that of an absolutely black body. For this reason an energy calibration of the spectral emissivity was made for the axial zone of the capillary.

In the visible range a determination of the specific spectral emissivity of the source was made by comparing its brightness with that of a standard incandescent lamp using a photoelectric method. The measurements were made by the method of integration of charge on a capacitor with the help of a photoelectric device for spectral-emission analysis. High accuracy is attainable since the shape of the light pulse does not depend on the wavelength. The charges on the integrating capacitor from the pulse and from the standard lamp were of the same level even though their photo-currents differed by a factor of 10^4 to 10^6. This was brought about by increasing the exposure time for the standard lamp to about 40 sec. The error in measurement of specific spectral emissivity does not exceed ±7% with a reproducibility of ±3%.

The determination of specific spectral emissivity in the 2500 to 4000 A ultraviolet range is carried out by means of a vacuum thermocouple with galvanometer, since a reliable standard reference source is not available.

Since the time constant of the thermocouple is much greater than the duration of the light pulse that is being measured, the ballistic method was used. The thermocouple was calibrated by measurements in the visible spectral range of the pulse source.

The measurements showed that the radiation of the pulse source in the 2500 to 6000 A range corresponds to the radiation of an absolutely black body at 39,000 ± 2000 K.

The apparatus is provided with a system for control of the electrical characteristics of the discharge, and for starting it by means of an external electrical signal. Rapid interchange of the capillaries is possible, and provision is made for transverse adjustment of the discharge chamber and the capillary.

At the present time, pulse sources of this type have found application in high-speed photography at extremely high frame-rates (10^7 frames/sec), for the energy calibration of optical instruments at high intensities, in the high-temperature pyrometry of gases, for obtaining absorption spectra of plasmas, and in gas dynamics research.