Nanosecond High Radiance Standard Source

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Spectral radiances R_λ and luminances B in the center axis of high density 8–20-nsec spark channels as produced by Nanolite sources were systematically studied by comparison with the emission from a calibrated dc-carbon arc. The maximum value of R_λ was 53 W cm^{-2} Å^{-1} sr^{-1} in 1 atm of air at 4850 Å with a breakdown voltage of 2.5 kV when the Nanolite (C = 2.9 nF, L = 2 nH) was charged slowly. This value increased to over 70 W cm^{-2} Å^{-1} sr^{-1} when the source was pulse charged. Saturation values of R_λ were 38 W cm^{-2} Å^{-1} sr^{-1} in 3 atm of argon and 60 W cm^{-2} Å^{-1} sr^{-1} in 32 atm of helium (slow charged). All values were reproducible to within 10%, the absolute error being estimated to be smaller than ±20%. Equivalent maximum blackbody temperatures of the channel surface in air were 62,000 K (pulse charged) and 38,000 K in argon and 54,000 K in helium (slowly charged). Maximum spectral radiant intensity in 1 atm of air was 0.18 W Å^{-1} sr^{-1} at 4850 Å (pulse charged).

Background

A reliable high radiance nanosecond standard source of continuous optical radiation was not readily available. Calibration of short light pulse sources was performed in the past for individual cases only. In this letter we report about the emission from a high density, short gap, <1-mm spark channel produced by the low inductance Nanolite light source.[1-4] This source was calibrated by means of a dc carbon arc[5] using a 20-nsec Kerr cell time shutter. The results were reproducible to within 10% in the extended series of observations. This demonstrated that Nanolite is useful as a high intensity nanosecond standard light source of continuous spectral emission. The radiances R_λ were measured in W cm^{-2} Å^{-1} sr^{-1} and the luminances B in cd cm^{-2}.

Arrangement and Measurements

In the arrangement shown in Fig. 1 both the Nanolite and the calibrating carbon arc are interchangeable at the same location. The center of the positive crater of the carbon arc or the center axis of the Nanolite is imaged on the slit before the S-4 photomultiplier with the slit width being approximately 1/10 diam of the enlarged channel image. Thus maximum R_λ values in the channel axis could be selected. Neutral filters (volume absorber) did reduce the Nanolite signals to those of the dc carbon arc. Interference filters of ~100-Å half-width provided spectral observation at 4850 Å, 4950 Å, and 5530 Å. The spread of R_λ values in succeeding shots could be reduced by electrode polishing.[2]

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The extensive series of shots indicated that 20% of all Nanolite signals were within 5% of the maximum value. Hence, the statistical average value within the top 5% was selected. The spectral transmission of the Kerr cell, open and pulsed, was obtained from observations of relative Nanolite signals.

Heating effects in the nitrobenzene of the Kerr cell shutter were studied and taken into consideration. The Kerr cell was kept open by dc voltage in the case of a slowly charged Nanolite. When pulse charged, the time jitter between Kerr cell gate and Nanolite light pulse of the first twenty shots was reduced to less than 5 nsec by electrode polishing.[3]

Results

Air, 1 Atmosphere

In Fig. 2 the spectral radiances of Nanolite KL-L 70 (C = 2.9 nF, L = 1.9 nH) at 4850 Å, 4950 Å, and 5530 Å as a function of gap length d are shown. The 70 source was charged slowly by a dc power supply, and the light risetime was 7 nsec with a half-width approximately 13 nsec in 1 atm of air. It is interesting to note that the radiance in this particular case does decrease by approximately $d^{-0.6}$, which means R_λ becomes smaller with increasing breakdown voltage U. The maximum value of 53 W cm^{-2} Å^{-1} sr^{-1} was observed at 4850 Å with a low voltage of 2.5 kV with d = 0.4 mm. The reason for the decline of R_λ appears to be due to the increasing channel volume with increasing gap length. Equivalent blackbody temperatures as obtained by the Planck formula do decrease from 48,000 K for 2.5 kV to 40,000 K for 4.1 kV. Opacities approaching unity in the center axis were observed in this laboratory by means of the Meiners-back mirror method[6] under comparable discharge conditions (to be published). The relative error of the measured radiances at 4850 Å and 4950 Å is ±10%. Figure 2 also contains

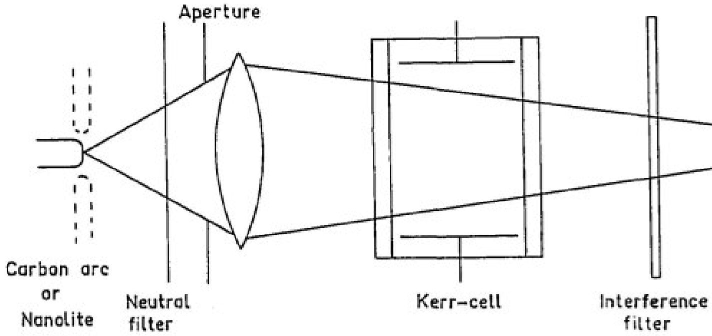

Fig. 1. Arrangement.

values of luminances B in candles cm^{-2} as calculated from the above temperatures.

Figure 3 represents radiances, luminances, and blackbody temperatures in 1 atm of air, however, the source being pulse charged[3] in this case at a constant gap, $d = 0.6$ mm. The pulse amplitude of the pulser was altered between 5 kV and 7 kV. The radiances do increase with the pulse amplitude, and maximum radiance was 74 W cm^{-2} $Å^{-1}$ sr^{-1} at 4850 Å with a 7-kV pulse. Equivalent blackbody temperatures are between 50,000 K and 62,000 K. The 5530-Å temperatures appear lower. This effect is probably not real and possibly is caused by the decreased accuracy of the observed Kerr cell transmission. Smaller radiances R_λ were observed with Nanolite sources of reduced capacity C. R_λ increases approximately as $C^{0.4}$ in case of $C > 0.5$ nF. The observed values are in Table I. This same relationship was confirmed by independent measurements.[7]

Values of spectral radiant intensity,

$$I_\lambda = \int R_\lambda df,$$

of the Nanolite were obtained from I_λ values of the carbon arc, which in turn were obtained by integrating the local R_λ values across the arc crater. The observation of the Nanolite was performed without imaging. Apertures were introduced for scattered light reduction.

Figure 4(a) shows I_λ of Nanolite 70 KL-L in 1 atm of air (slowly charged) as a function of gap length d. The source was pulse charged in Fig. 4(b) with pulse amplitude a constant value, 7.2 kV.

Argon and Helium

Radiances in argon in the pressure range between 1.2 atm and 5 atm were observed with a constant gap of 0.6 mm. The gap was seen side on through a plastic cylindric tube in this case. The transmission of the plastic window was measured to be 82% with 4850 Å, 85% with 4950 Å, and 80% with 5530 Å. R_λ does increase with pressure (voltage) but reaches a saturation plateau beyond 3 atm.[4] Maximum radiance with 4850 Å was 32 W cm^{-2} $Å^{-1}$ sr^{-1} as seen through the plastic window. The radiance of the channel surface amounts to 38 W cm^{-2} $Å^{-1}$ sr^{-1} when the window absorption is considered. The values are 27 (32) W cm^{-2} $Å^{-1}$ sr^{-1} at 4950 Å and 14.5 (18) W cm^{-2} $Å^{-1}$ sr^{-1} at 5530 Å. The source was slowly charged. The equivalent blackbody temperature of the channel surface in case of R_λ saturation was between 35,000 K and 38,000 K.

Saturation was reached in helium with pressures

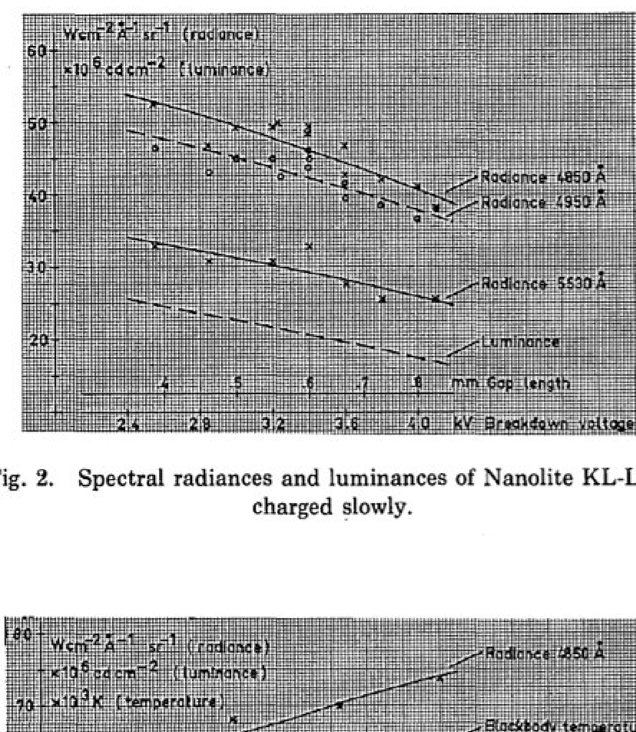

Fig. 2. Spectral radiances and luminances of Nanolite KL-L 70, charged slowly.

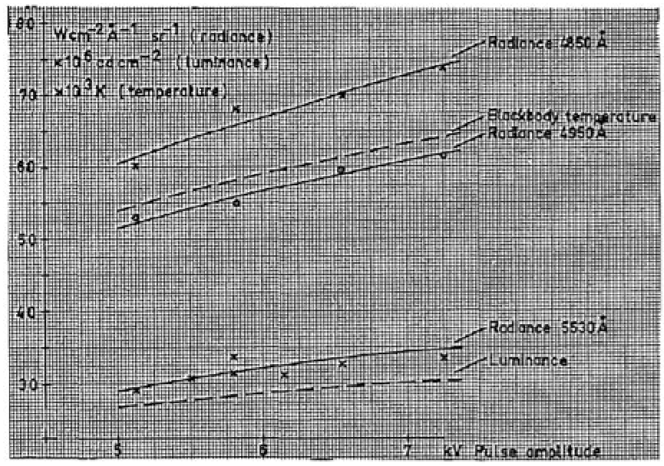

Fig. 3. Spectral radiances, luminances and blackbody temperature of Nanolite KL-L 70, pulse charged, gap length 0.6 mm.

Table I. Radiances of Different Sources[a]

Source	nF	nH	4850 Å	4950 Å	5530 Å
70 KL-L	2.9	1.9	53	49	33
65 KL-M	1.2	2.2	35	34	21
68 KL-K	0.6	2.1	26	25	17

[a] Breakdown voltage 2.5 kV.

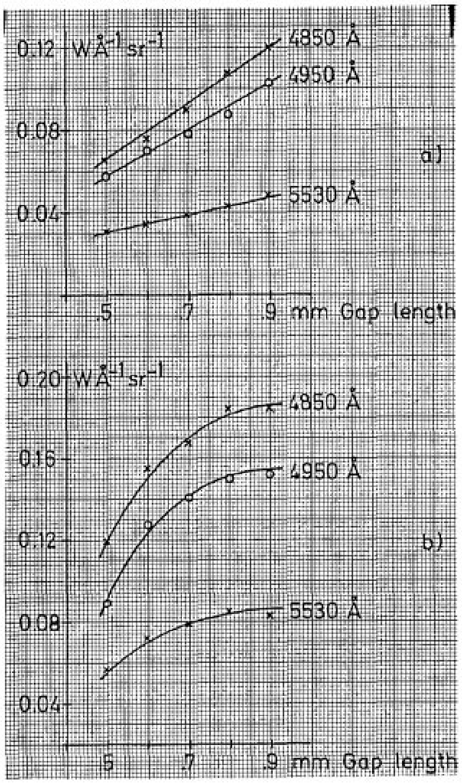

Fig. 4. Spectral radiant intensities of Nanolite KL-L70 (a) slowly charged, (b) pulse charged, pulse amplitude 7.2 kV.

exceeding approximately 30 atm, and maximum R_λ values in helium (slowly charged) are higher by a factor of approximately 1.65 than those in argon.[4] Thus a maximum saturation radiance of the channel surface of approximately 60 W cm^{-2} Å^{-1} sr^{-1} at 4850 Å is expected in helium (without window) with the blackbody temperature being 53,000 K in this case. When the source is pulse charged these values probably would be higher.

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