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TEMPERATURE OF SINGLE CARBON PARTICLES HEATED BY CO_2 LASER RADIATION

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UDC 536.521:621.383

Of great interest in the study of the interaction of strong laser radiation with a solid combustible absorbing aerosol (within the framework of the single-particle approximation) is the investigation of the temperature dynamics of a single particle located in an intense optical field.

The nonperturbing registration method used in this study to determine the temperature of a single particle is the color method [1], which is fast and highly accurate.

We investigated in the experiment the dynamics of the temperature of single particles of lampblack of grades PM-75 and PM-100 with sizes from 100 to 500 μm, which were placed in the field of the emission of a cw regular-production LG-25A laser. The power density of the acting radiation was varied in the range $0.8 \cdot 10^6 - 1.3 \cdot 10^7$ W/m², and the particle shape was close to spherical. The investigations were carried out in the ambient air atmosphere. The particles were placed on the end part of a quartz filament of diameter 8-10 times smaller than that of the particle.

The visible radiation from the burning particle was split into two beams that passed through interference light filters with passband maxima $\lambda_1 = 692$ nm and $\lambda_2 = 429$ nm and with passband half-widths 12 and 10 nm, respectively. The radiation receivers were FÉU-28 and FÉU-36 photomultipliers.

At applied intensities $I \geq 0.5 \cdot 10^7$ W/m², neutral attenuators were placed between the interference light filters and the photomultipliers, to permit the latter to operate in a linear regime.

The particle temperature was calculated from the formula

Translated from II Vsesoyuznoe Soveshchanie po Rasprostraneniyu Lazernogo Izlucheniya v Dispersnoi Srede. Tezisy Dokladov (Second All-Union Conference on Propagation of Laser Radiation in Disperse Medium. Summary of Proceedings), Part II, pp. 134-136, 1982.

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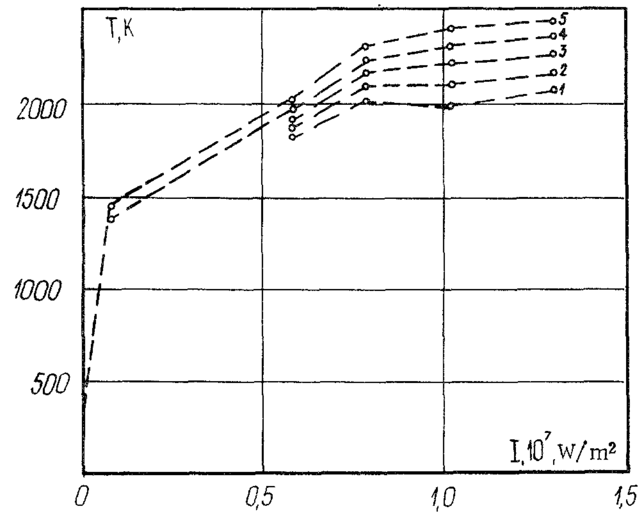

Fig. 1. I-d=100 μm; 2-200 μm; 3-300 μm; 4-400 μm; 5-500 μm.

$$T = \frac{\frac{hc}{k}\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right)}{\ln\frac{U_1}{U_2} - \ln\frac{\alpha_1(\lambda_1)}{\alpha_2(\lambda_2)} - \ln\left(\frac{\lambda_2^5 D_1(\lambda_1) B_1(\lambda_1, V_1)\Omega_1}{\lambda_1^5 D_2(\lambda_2) B_2(\lambda_2, V_2)\Omega_2}\right)} \tag{1}$$

where λ is the wavelength; h, Planck's constant; c, speed of light; k, Boltzmann's constant; $\alpha_i(\lambda_i), T$, degree of blackness and the temperature of the investigated body; $D_i(\lambda_i)$, light-filter transmission function; Ω_i, angular aperture of the photoreceiver; $B_i(\lambda_i, V_i)$, a coefficient that depends on the type of photoreceiver, on its spectral characteristic, and on the polarity of the supply V_i; and U_i is the signal from the photomultiplier. Calculation of the third term in the denominator of (1) is difficult because of the difficulty of determining the coefficients $B_i(\lambda_i, V_i)$ and Ω_i. To use (1) in practice the setup was therefore calibrated against an incandescent lamp with a tungsten filament. The spectral dependence of the degree of blackness of the tungsten in the visible region of the spectrum permits its use as a calibrating body [2]. Since the calibration curve plotted in coordinates $\ln\frac{U_1}{U_2}, \frac{1}{T}$ is linear, the quantity

$$\ln\frac{\lambda_2^5 D_1(\lambda_1) B_1(\lambda_1, V_1)\Omega_1}{\lambda_1^5 D_2(\lambda_2) B_2(\lambda_2, V_2)\Omega_2}$$

is determined by the intercept of the calibration line on the ordinate axis. The relative error of the experimental results is in the range 6-8%.

The investigations have shown that the temperatures to which the hot lampblack particles were heated at constant value of I depend on the initial particle sizes. The dependence of the particle temperature on the power density of the applied radiation for a given initial size is shown in Fig. 1.

When an aluminum substrate was used in lieu of a quartz filament, a lower average particle energy was recorded. Thus, at $I = 0.8 \cdot 10^6$ W/m^2, owing to heat transfer to the aluminum substrate, the average particle temperature was lowered by 200-300°K compared with the temperature on the quartz filament.

In the course of the reduction of the experimental data we observed temperature spikes in the process of the heating of the sooty particles. The spike duration was of the order of 0.01 sec. In a set of experiments with particles of Ékibastuz hard coal, similar results were obtained and the temperature spikes were more pronounced and of longer duration. All this leads to the conclusion that the temperature spikes correspond to ignition of the volatile substances.

The maximum temperatures of the volatile-matter spikes in the case of the investigated sooty particles, determined from the experimental results, were the following: $2250 \leq T \leq 2450$, $2150 \leq T \leq 2250$, and $1950 \leq T \leq 2100$°K at $I = 1.3 \cdot 10^7$, $I = 1.02 \cdot 10^7$, and $I = 0.8 \cdot 10^7$ W/m^2, respectively.

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