Accelerated precipitation of water fogs due to acoustic action of a CO_2 laser pulse

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Accelerated precipitation of water fogs, induced by the acoustic action of a pulsed CO_2 laser with energy in the range 0.8–3.2 J/cm^2 and pulse duration $\sim 1\ \mu s$, is observed.

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Effects arising due to the action of CO_2 laser radiation on water particles in artificial fogs and natural clouds,[1,2] including vaporization of particles in a pulsed radiation field and formation of a transmission channel,[3] have been thoroughly studied. It has been shown that when radiation interacts with particles in water fogs under certain conditions, the form of the particle-size distribution function in the region of propagation of the beam changes.[2,4] In this case, the particle-size spectrum changes either due to fragmentation of drops accompanying their thermal explosion or due to condensation of vapors formed by drops evaporating in the radiation field. According to the data in Ref. 3, transmission through water fogs occurs at energy densities of pulsed 10-micron radiation equal to 6–20 J/cm^2.

In this work, we observed an increase in the sedimentation rate of artificial water fogs due to the acoustic perturbation created in the aerosol medium by pulsed CO_2 laser radiation. The characteristic feature of the effect is that it arises with energy densities that are much lower than those involved in the formation of the transmission channel and much later than the passage of the perturbing laser pulse.

We have investigated the effect of the perturbation created by radiation from a powerful pulsed LAD-2 CO_2 laser[5] on particles in artificial water fogs located outside the region of propagation of the laser beam. When 10-micron radiation propagates in water fogs, part of the energy of the laser pulse is absorbed by particles and goes into heating the gas. In this case, an acoustic disturbance is generated in the region of the beam.[6] Prior to the action of the radiation, the water-particles–saturated-vapor system is in a state of thermodynamic equilibrium. When the acoustic disturbance occurs, the partial pressure of the water vapor increases, which leads to a breakdown of equilibrium between the vapor and the water particles and to condensation of vapor on the surfaces of the particles. This, in turn, leads to particle growth and a higher rate of particle precipitation.

In order to monitor the changes in the dispersed phase, we probed the fogs obtained in a $1.8\times1\times1$-m Plexiglass chamber with beams from two He-Ne lasers; one beam passed through the chamber along the axis of the tubular CO_2 laser beam, and the other passed parallel to the CO_2 laser beam at a distance of 22 cm from its optic axis. In order to avoid the effects of defocusing of the probing radiation due to possible formation of thermal or acoustic lenses,[6] the radiation from the first laser was focused on a photodiode. The time constant of the recording channel was $\sim10^{-5}$ s. The intensity of the second probing beam was recorded by a photodetecting system on a strip chart of an automatic plotter with a large time constant. The recording system of the first and second beams could be interchanged during the course of the experiments. The starting particle concentration in the water aerosol in all experiments was 5×10^4–10^5 cm^{-3}. The maximum in the particle-size distribution occurred at a radius of 0.5–1 μm. In the absence of irradiation, the precipitation time of the fogs, determined from the order-of-magnitude decrease in attenuation of the probing beam, constituted $\sim$10–15 min.

When the cloud of artificial fog was irradiated by a CO_2 laser, approximately 15 s after the time of action of the radiation pulse, a sharp jump in transmission, whose maximum reached 30% of the signal of the probing beam in the chamber without the aerosol, was recorded in the probing channel with high time constant (Fig. 1a). In the high-speed channel, an appreciable increase in attenuation was recorded along the axis of the CO_2 laser beam 250 μs after passage of the radiation pulse, as can be seen in Fig. 2. It should be noted that the rate of precipitation of fogs increases when clouds are irradiated by a CO_2 laser beam with a continuous cross section. The effect was most

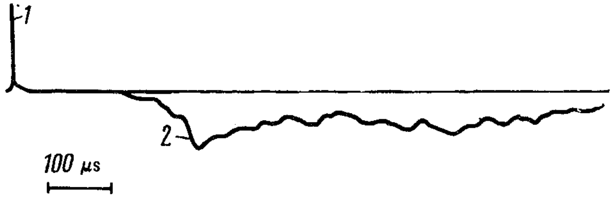

FIG. 1. Fragment of the trace of the transmission of a water aerosol for He-Ne laser radiation. 1—Control aerosol injection; 2—transmission of aerosol after action of CO_2 laser radiation, pulse duration 1 μs, energy density 3.2 J/cm².

strongly manifested when the aerosol medium was irradiated two to three minutes after the formation of the fog and became weaker with repeated injection of water fogs without first drying the chamber, which apparently is attributable to displacement of the particle spectrum toward smaller particle sizes.

Observations of the magnitude of transmission of water aerosol under different incident energy densities show that the relative magnitude of transmission of the water aerosol increases almost linearly with increasing incident energy density nearly to 3 J/cm². However, because of the nonlinear absorption of laser radiation by the aerosol medium, the efficiency of transmission increases with increasing incident radiation energy density, which is apparently explained by the fact that at energy densities approaching 3 J/cm² and higher, evaporation of large drops containing a considerable amount of water begins to have an appreciable effect on the increase in the partial pressure of water vapor.

Estimates of the magnitude of the increase in particle sizes accompanying the breakdown of equilibrium between the vapor and the water drops due to the increase

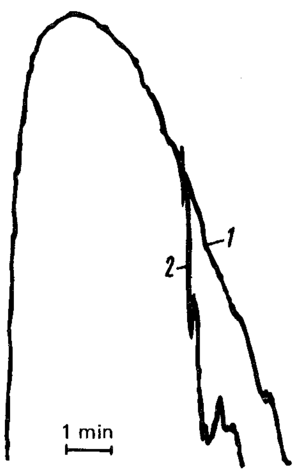

FIG. 2. Onset of attenuation of He-Ne laser radiation on the axis of the CO_2 laser beam. 1—CO_2 laser pulse, 1 μs, 3.2 J/cm²; 2—power level of He-Ne laser radiation passing through an aerosol, in relative units.

in the partial pressure of water vapor resulting from the acoustic disturbance, based on conservation of the balance of water molecules in the condensed and vapor phases, agree reasonably well with the experimental results. We should also note the good coincidence of the transmission time of the sound wave through the water aerosol and the time at which the effects are first observed.

Thus we have observed the condensation of vapor in fogs and, correspondingly, an increase in the rate of sedimentation of enlarged water drops as a result of the action of pulsed low-energy-density CO_2 laser radiation on the fog beginning at 0.8 J/cm^2. The observed effects are attributable to a shift in the thermodynamic equilibrium of the water-particles–saturated-vapor system and to an increase in the drop size due to condensation accompanying the passage of a weak sound wave, arising with the propagation of the pulsed laser radiation.

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