# EXPERIMENTAL INVESTIGATION OF THE MECHANISM OF BRIGHTENING OF A DISPERSED MEDIUM MOVING IN THE FIELD OF HIGH–POWER CHEMICAL HF CW LASER RADIATION AT LOW AMBIENT PRESSURE

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*The mechanism of enhanced transparency (brightening) of a layer of carbon and magnesium oxide particles of submicron size moving at a velocity of* 1200 m/s *at a reduced ambient pressure of* 50 Pa *is investigated. The layer of particles was exposed to a* HF *cw laser radiation with power density in the beam up to* 30 MW/m$^2$ *and beam cross section of* 10 cm$^2$*. The transparency is shown to be enhanced first of all due to removal of particles from the field of high–power laser radiation. Transformation of the dispersed particle composition after exposure to laser radiation has been evaluated.*

The development of a number of new promising directions with the use of high–power lasers (long–range laser detection and ranging, energy transfer to remote objects, and remote sensing with active effect on a medium) calls for the study of the high–power cw laser radiation propagation in finely dispersed media.

Various nonlinear effects accompanying the interaction of high–power laser radiation with such media are of significant interest.

The characteristics of dispersed particles, laser radiation parameters, and ambient pressure affect strongly different processes accompanying such interaction. Dispersed media created by means of special pyrotechnical generators are of great practical interest. As a rule, such media are characterized by a complex structure, dispersed and element composition, and propagate at rather large velocities relative to a source and often at reduced ambient pressure.

At present the interaction of high–power laser radiation with such media under above–indicated conditions have not yet been adequately investigated in spite of a lot of papers devoted to the problem as a whole.

This paper is devoted to the experimental study of the mechanism of brightening of a layer of fast moving finely dispersed particles, generated by a pyrotechnical generator, in the field of high–power chemical HF cw laser radiation at a reduced ambient pressure of 50 Pa.

## EXPERIMENTAL INSTRUMENTATION AND TEST PROCEDURE

An experimental complex consisted of the following systems: a source of high–power laser radiation (chemical HF cw laser with output power of about 30 kW), experimental assembly, pyrotechnical generator of a dispersed medium, optical scheme, and measuring and automated control systems. These systems were fully described in Ref. 1, so only their main peculiarities are given below.

The experimental assembly contained a measurement channel equipped with eight windows to insert and to extract a beam of acting radiation and to conduct measurements as well as a spherical composite chamber. Optics of windows was shielded from particles by special facilities. Devices for regulation and measurement of particle flux density were placed inside the assembly.

The generator of finely dispersed medium of pyrotechnical type was butted to the top end of the measuring channel. The generator produced the flux of carbon and magnesium oxide particles moving at a velocity of about 1200 m/s. The particle flux axis was perpendicular to the plane in which the axes of optical input windows lay. The mean particle size was about 1 μm, and the mass rate of flux varied from 1.5 to 20 g/s. Inner chamber of the experimental assembly formed a close volume pumped out to a pressure of about 50 Pa.

A particle collector involved an isokinetic collector (impactor) equipped with supersonic collector and a rotating disc with a few pieces of object glass clamped on it.

The collector axis coincided with the particle flux axis and was perpendicular to the disc rotation plane, with the disc rotation axis being displaced from the collector axis. Before sampling the collector was closed by a shutter, which was open during one revolution of the disc when particles settled on pieces of object glass.

The optical scheme used for experiments is shown in Fig. 1. It includes the acting and sounding beam channels. The high–power HF cw laser radiation was collimated into the region of interaction with moving finely dispersed medium by means of the copper long–focus spherical mirror *1*. The cross section of the acting beam was 47×25 mm in the region of measurement channel (maximum dimension was oriented in the direction of motion of particles).

The intensity of radiation acting on the front surface of the particle layer was determined from readings of the cooled thermocouple calorimeter *25*. The degree of attenuation of the radiation (transparency of the path) was measured in two independent channels by means of the low–inertia bolometric power meters *12* and *28* that transmitted the incident radiation and of the two MG–30A pyroelectric receivers of optical radiation *16* and *21*. The receivers were placed into the integrating spheres *15* and *20* whose input holes were covered by the modulator discs *17* and *22*. The lenses *14*, *23* and *24* were used to match the beam cross section with the input aperture of the receivers.

The radiation of the LGN–302 optical quantum generator *13* with a wavelength of 0.63 μm was used as a sounding beam. The diameter of the sounding beam was 5 mm, it was directed on the acting beam path by means of the flat mirror *11* with an angular deflection of about 2°. The sounding beam power was measured by the receiver *7* (PMT–62).

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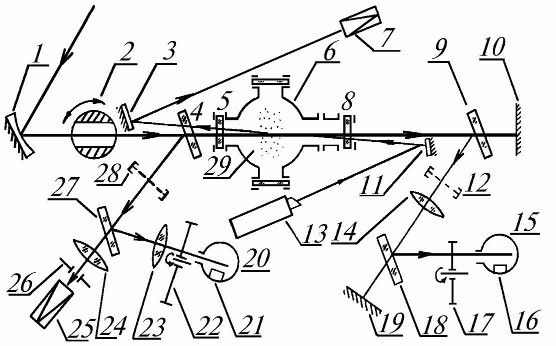


*FIG. 1. Optical scheme: 1) spherical mirror; 2) shutter; 3) and 11) flat folding mirrors; 4), 9), 18) and 27) beam–splitting plates; 5) and 8) windows for collimated beam (CB); 6) measurement channel; 7) PMT–62; 10) and 19) absorbers; 12) and 28) wire–gauze bolometers; 13) LGN–302 laser; 14), 23) and 24) lenses (CB); 15) and 20) integrating spheres; 16) and 21) MG–30A pyroelectric receivers; 17) and 22) modulators; 25) calorimeter; 26) diaphragm; 29) dispersed medium.*

The experimental procedure provided delayed start of the pyrotechnical generator of dispersed medium from starting and forcing into the operation regime of the radiation source. It made it possible to calibrate the path without dispersed medium. The acting beam was periodically covered with a frequency of 0.4 Hz during the experiment by means of a mechanical shutter. The collection of the dispersed medium samples began at an instant when the acting beam was fully covered by the shutter.

## OBSERVED RESULTS AND CONCLUSIONS

The mechanism of interaction of HF cw laser radiation with finely dispersed particles was investigated in the range of power density of the acting radiation from 0.2 to 30 MW/m$^2$.

During the experiments the essential enhancement of the layer transparency was observed as the laser beam intensity rised above 3 MW/m$^2$. It is highly improbable that the sublimation mechanism of brightening in the region of interaction, selected in Ref. 2 as a principal mechanism at reduced ambient pressure, starts to manifest itself at so low power density in the beam.

The enhanced path transparency for the sounding beam attendant to brightening upon exposure to the acting radiation is another argument in favor of this assumption. Otherwise, in case of particle size decrease due to sublimation (or fragmentation), the increased turbidity of the path would be observed due to the increase of the attenuation efficiency factor of the sounding radiation with a wavelength of 0.63 μm if the particle size decreased down to the value close to the given wavelength. Such effects are described in detail, for example, in Ref. 3.

An analysis of results of sampling of particles of a dispersed medium shows that the mass of a sample collected at the flux axis immediately under the beam path substantially decreases upon exposure to high–power HF cw laser radiation.

The collector disc is shown in Fig. 2 with indicated sample cyclogram from which this effect is seen. The average sample mass is shown in Fig. 3 as a function of the power density of acting radiation.

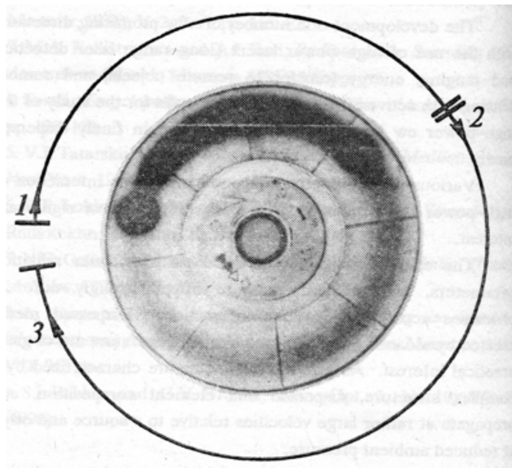


*FIG. 2. Photograph of the disc: 1) start of sample collection, with the shutter being closed; 2) moment of full opening of the shutter; 3) finish of sample collection.*

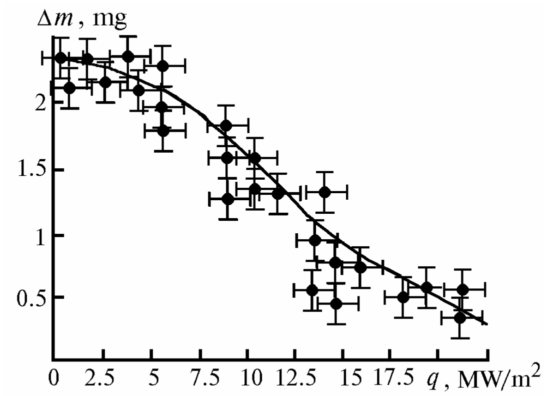


*FIG. 3.*

Thus, the mechanism of intense removal of particles from the beam path can be considered to be the basic mechanism of brightening of the dispersed particle flux produced by the pyrotechnical generator in a vacuum.

Manifestation of this mechanism is possibly connected with the peculiarities of the finely dispersed particle formation in the pyrotechnical generator. Thus, the solid phase of combustion products condenses when moving through a supersonic nozzle of the generator and forms relatively friable (Fig. 4) secondary soot conglomerates that entrain some residual gases. In the field of high–power laser radiation, particles are quickly heated that leads to removal of some gaseous inclusions. As a consequence, particle gains reactive momentum whose direction is in general opposite to that of the gradient of the intensity of radiation incident on the particle. The character of fouling of the window optics with particles testifies this fact.

These circumstances lead to the sharp change of particle trajectory and their removal from the radiation field resulting in the enhanced path transparency (brightening).

In addition, investigation of the dispersed composition of particles collected after their passage of the path showed some decrease of the average particle size from 1.05 to 0.83–0.9 μm as a consequence of partial breaking of relatively weak bonds in the secondary soot conglomerates caused by removal of gaseous inclusions.

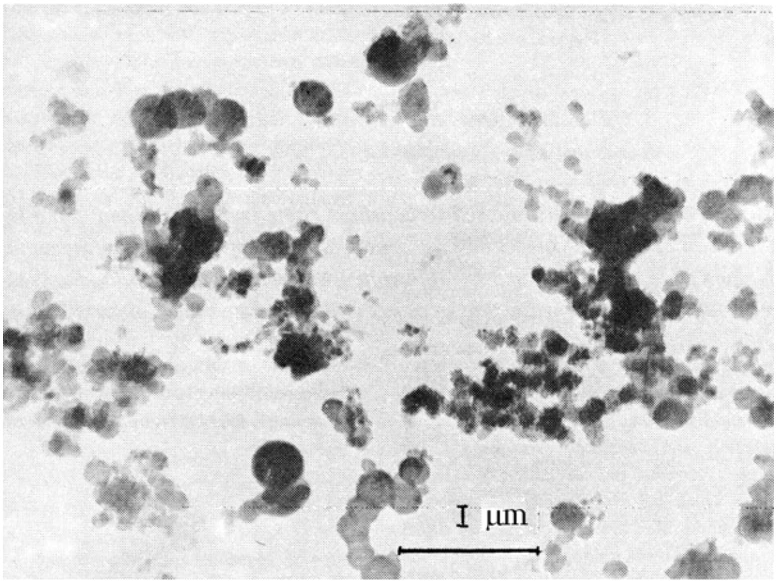


*FIG. 4.*

Thus, our investigations elucidate the mechanism of brightening of a dispersed medium containing a mixture of carbon and magnesium oxide particles upon exposure to high–power HF cw laser radiation at reduced ambient pressure.

In connection with the above–indicated peculiarities, the study of the effect of the angle between the vectors of particle velocity and laser radiation propagation on the parameters of brightening of such dispersed media becomes very urgent.

## REFERENCES


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