NONLINEAR EFFECTS AT INTERACTION OF HIGH POWER RADIATION OF A CW HF LASER WITH A MOVING DISPERSE MEDIUM UNDER LOW PRESSURE

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In this paper we present an experimental study of the transmission of a layer of small particles of carbon and magnesium oxide moving with a speed of 1200 m/s *under the action of a high-power beam from a cw HF laser. Radiant exitance of laser reached* 20 MW/m² *within the beam cross section of* 25×50 mm. *In our experiment we have observed the effect of clearing up of such a medium at enhanced radiant flux density of the beam. We have also determined the value of radiant flux density threshold at which the clearing up is of stationary behavior. In this study we managed to reveal the dependence of the volume extinction coefficient of such a medium on the radiant intensity and mass density of the particles flow. The data obtained in this study show that the mechanism of clearing up of such a medium differs from earlier known models. The latter result demonstrates the necessity of studying this process in more detail.*

With the advent of space-based high-power lasers, first of all, cw HF(DF) chemical lasers, the solution of a number of urgent problems associated with finely disperse aerosol particles and particles of cosmic origin exposed to laser radiation were made possible. Among these problem are the remote sensing of the atmosphere and the problems of active action on the finely dispersed particles of anthropogenic origin polluted the space and upper atmosphere, which recently are growing in importance. It should be noted, that characteristics of such finely dispersed particles differ from those of the atmospheric aerosol.

In this connection, experimental investigations of high-power laser radiation interaction with a moving disperse medium under conditions of low ambient pressure become an urgent problem.

Among a number of silient features of these investigations, responsible for their complex character, the need to provide the high radiant flux density (up to several tens of megawatt per square meter) together with a large cross section of laser beam should be mentioned first of all, as well as the need to carry out the measurements under conditions of such radiation parameters.

In this paper the experiments studying the processes of interaction of high-power radiation of cw HF chemical laser with a moving sooty disperse medium is described. The medium was created by a special pyrotechnical generator under conditions of ambient pressure lowered to 50 Pa. The aim of the experiments is to determine phenomena appearing at such interaction and to obtain some quantitative characteristics of such processes.

The experimental complex includes the cw HF chemical laser with output radiant flux up to 30 KW, experimental assembly, pyrotechnic generator prodicing a disperse medium, optical scheme, measuring and automatic control systems, and also ancillary systems.

Flow of finely dispersed particles is formed with pyrotechnic generator within internal volume of the evacuated hermetic experimental assembly. This gas–disperse flow contains 70% of solid phase (by mass) consisting of equal portions of pyrolytic carbon and magnesium oxide particles. Average size of particles is about 1 μm, the velocity is in order to 1200 m/s (in the region of optical windows).

To input and output laser radiation and perform measurements, the assembly is completed with optical windows which axises are in plane with each other. The "force" radiation is incident on the disperse medium layer perpendicular to the velocity of particles. Assembly is also completed with arrangements for controlling density of gas–disperse flow and sampling.

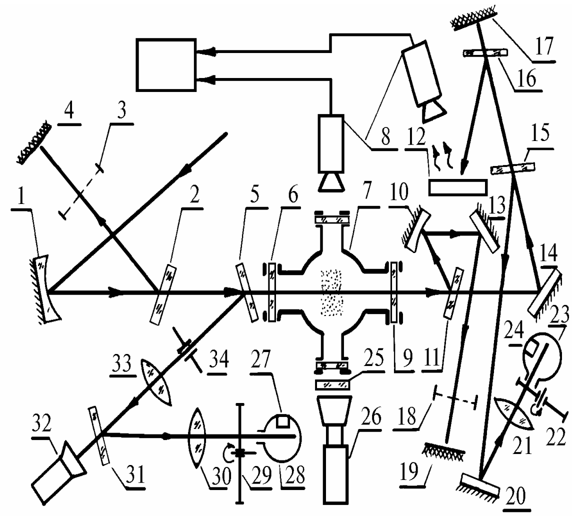

FIG. 1.

All basic elements of the complex, except the optical scheme, were described in Ref. 1.

The optical scheme is shown in Fig. 1, where *1* and *10* are the spherical focusing mirrors; *2*, *5*, *11*, *15*, *16*, and *31* are the dividing plates; *3* and *18* are the bolometric power measurers of duct type; *7* is the measuring channel; *6* and *9* are the optical windows; *13*, *14*, and *20* are the flat mirrors; *4*, *17*, and *19* are the absorbers; *12* is the blacked cooper thermoabsorbing screen; *8* is the thermovision scanner; *21*, *30*, and *33* are the lenses; *22* and *29* are the modulators; *23* and *28* are the integrating spheres; *24* and *27* are the pyroelectric MG-30A detectors of optical radiation; *34* is the diaphragm; *32* is the thermocouple calorimeter; *25* is the KS-15 filter; and, *26* is the SKS-IM high-speed film camera.

Optical windows of measuring channel and lenses are made of BaF_2 (CaF_2) while dividing plates are KI quarts.

The laser beam is collimated in the disperse medium with the cooper spherical mirror *1* 1.5 m in focus length and more than layer thickness of disperse medium in waist length. Sizes of cross section of the beam in the necking zone depend on the laser operating mode, and they are about 50×20 mm (the larger size is oriented along the particles motion direction). The ray path within the optical scheme is clear from Fig. 1.

The measurements of the radiation parameters were performed at input of the experimental assembly with the use of "Coherent Radiation" (model 203, USA) cooled thermocouple calorimeter *32* (see Fig. 1), bolometric power measurer *3*, and the MG-30A pyroelectric detector *27*. Parameters of radiation passing through the disperse medium layer were measured in two channels with similar devices *18* and *24*.

To estimate the radiant flux density distribution over the plane perpendicular to the ray direction, a portion of output radiation was directed onto the 30–mm thick cooper plate with a blacked surface where the beam cross section was imaged at the output from the disperse medium layer. The temperature field in the zone of heating was recorded with T 800 "AGEMA" thermovision system.

Thermal fields of particles in the irradiated zone were observed with this system also for which purpose the thermovision scanner was placed at one of the windows (see Fig 1.). In doing so the special build–in filter cut off the scattered by particles laser radiation.

Experimental technique envisaged the start-up of the generator of disperse medium with a time delay with respect to lasing that allowed us to record the data from all the sensors at the lack of particles in the measuring channel and to determine scaling coefficients for sensors data at input and output of the layer.

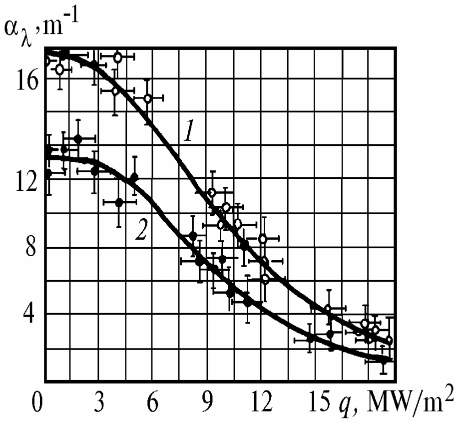

FIG. 2.

Propagation of the cw HF chemical laser radiation through the layer of finely disperse particles was studied in the range of radiant flux density from 0.2 to 20 MW/m^2. Typical dependences of the volume extincion coefficient of radiation $\alpha(\lambda)$ due to the layer at various particles flow densities (0.27 kg/m^2/s (curve *1*) and 0.14 kg/m^2/s (curve *2*)) on the intensity of acting radiation q is shown in Fig. 2. The existence of two portions is characteric for these dependences: quasilinear one, within which screening properties slightly depend on the intensity of the acting radiation, (up to 3 MW/m^2) and the nonlinear one. Existence of the nonlinear portion points to the clearing up of the particles layer when radiant flux density exceeding a threshold value.

Figure 3 shows the volume extinction coefficient as a function of a particles flow density at various levels of the radiant flux density. These dependences are linear in the investigated range.

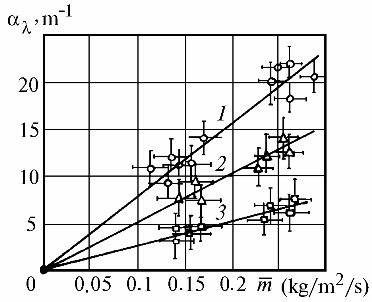

FIG. 3. Volume extinction coefficint vs particles flow density at radiant flux density of 3 *(1),* 9 *(2), and* 13 MW/m^2 *(3).*

The volume extinction coefficient as a function of the radiant flux density and a mass density of a particles flow is in agreement with current concept of the clearing up of disperse media,[2] as a whole. However, the value of the radiant flux density corresponding to the start of active manifestation of nonlinear phenomena was obtained in our experiments to be about 3 MW/m^2. At the same time, there is a lot of papers devoted to experimental study of both individual sooty particles[3] and low density aerosols[4,5] exposed to high-power optical radiation, which testify that such nonlinear phenomena could be observed at the essentially higher radiant intensity. For example, in Ref. 5, the clearing up of a sooty aerosol under the low ambirnt pressure was observed at the radiant flux density of the order 100 MW/m^2 and more.

Presumably, such low threshold of the beginning of clearing up is mainly due to features of disperse particles formed in the pyrotechnic generator as a result of condensation of the products of the special charge combustion. In addition, it should be noted, that, as a rule, a short-focus optical system is used in such experiments to reach the high radiant intensity. Thus, the focal volume is rather small and characterized by strong inhomogeneity of the radiant flux density distribution both along the path and at the cross section of laser beam, that brings about the increase in inevitable errors in determination of parameters of acting radiation and clearing up process.

When observing the heated particles in the irradiated zone, the essential fall of particles temperature with the depth of disperse medium was noticed. On the thermogram shown in Fig. 4, the front surface of a particles layer is of a temperature about 1700–2000 K, whereas rear one is of 900–1000 K being exposed to laser radiation with radiant flux density about 7 MW/m^2. In agreement with Ref. 4 at the pointed temperature and parameters of acting radiation, the time of sublimation of carbon particles is about tens of seconds, whereas the time the particles being under exposure of radiation is no more than 5 μs in this case.

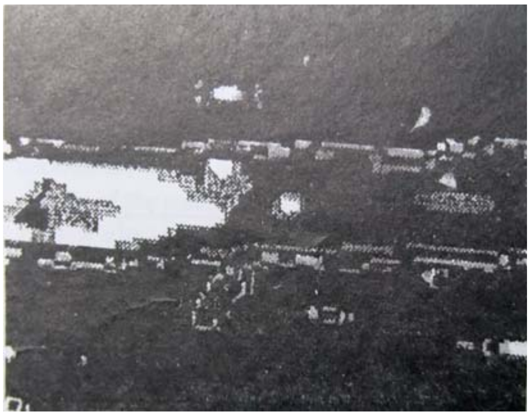

FIG. 4.

This circumstance indicates that the mechanism of clearing up of such a disperse medium differs from sublimation that set aside in Ref. 5 as a basic one under conditions of low ambient pressure.

Thus, in the experiments we have found the effect of clearing up of the sooty finely disperse medium to manifest itself at the radiant flux density greater than 3 MW/m^2 under conditions of pressure lowered to 50 Pa. Obtained data differ from some results of other experiments that show the necessity of further investigations of the process of the cw high-power laser radiation propagation through similar disperse media under low pressure and the mechanisms of clearing up in more detail.

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