LASER ANNEALING OF TRANSMISSION OPTICS ELEMENTS OF A WIDE-APERTURE CO_2 LASER

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Received June 10, 1997

It is established that the intensity of the H_α *line in integral spectra of a specimen irradiated sequentially by 5–6 laser pulses with energy density* $\le 2–3$ J/cm^2 *at* $\le 15–20$ min *intervals decreases, which is accompanied by the increase of the surface damage threshold and the decrease of the damage probability at pre-threshold intensity of the laser radiation. The effect retains* 1–3 h *after irradiation of alkyl halide crystal and the lifetime of optical elements fabricated from* KCl *is increased, on average, three times.*

Surfaces damage of optical elements of wide-aperture pulsed CO_2 lasers generally occurs at lower laser radiation intensity as compared to the bulk radiation-damage threshold of optical materials. Therefore, the study of the effects that increase the resistance of transmission optical element surfaces to laser radiation is of particular interest.

By now several physical mechanisms initiating surface damage under the action of laser radiation have been suggested. The decisive role of heating of absorbing inclusions is established in Refs.1–5. The assumption that the breakdown thresholds decrease due to the presence of physical surface defects which concentrate lines of force and thereby produce a substantial increase in the light wave field strength in the vicinity of defects is proposed in Ref. 6. The influence of the surface roughness s on changes of the threshold breakdown electric field E_{th} is established in Ref. 7, where the empirical relationship $E_{th} \sim s^{-m}$ $(0.5 < m < 0.75)$ is suggested.

The above mechanisms explain well the experimental data obtained in the visible spectral range. However, there are a number of facts (the surface breakdown threshold does not depend on the detect size, this threshold increases as the surface absorption decreases, and it decreases as λ^{-2} in the middle IR range) that cannot be explained within the framework of these models. They can be explained if the water adsorbed on the surface is considered to be of primary importance for the formation of laser breakdown (see Refs. 8 and 9). The effect of laser cleaning consisting in the increase of the breakdown threshold under repeated irradiation of the same surface area was explained on the basis of these assumptions. However, technology for application of this effect was not proposed. In addition, subsequent investigations have found that two stages of the surface damage can be distinguished (see Ref. 5), namely, initiation of the breakdown plasma and surface cracking on heating by the UV plasma radiation.

To develop a method for increasing the surface breakdown threshold of optical elements, integral emission spectra of plasma formations were recorded. A TEA CO_2 laser with a pulse duration of 40 μs was used as a radiation source. The laser energy density was varied from 1 to 20 J/cm^2, the beam spot area in the plane of irradiated crystal was ~100 cm^2.

It was found that repeated irradiation by single pulses with energy density $W \le 2–3$ J/cm^2 caused not only the increase of the surface breakdown threshold but also the significant decrease of the damage probability P at pre-threshold laser radiation intensity (see Fig. 1).

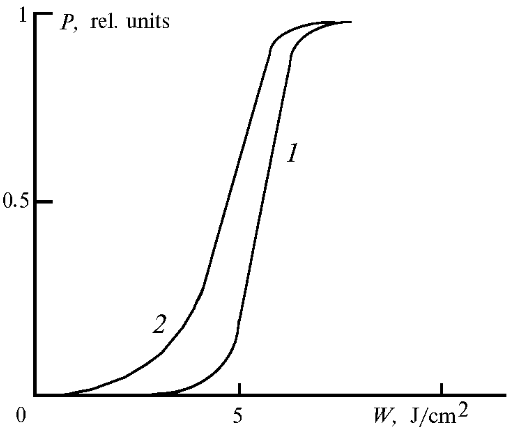

FIG. 1. Dependences of surface damage probabilities of optical elements fabricated from KCl *with (1) and without (2) preliminary laser irradiation.*

The effect of the threshold increase retains 1–3 h after irradiation of the alkyl halide crystal and is most pronounced when the pulse intervals do not exceed 15–20 min.

To obtain the dependence of the damage probability, we use the data on radiation resistance of

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89 optical elements. The thresholds of plasma formations were ~ 3–6 J/cm^2.

The study of the integral spectra of the plasma formations showed that broadened lines of the air components (mostly N II), atoms of optical element material, and the H_α line at λ = 656.28 nH are Host intense (see Fig. 2). Therewith, the H_α line intensity decreased under sequential action of a train of 5–6 laser pulses with close energy densities (see Fig. 3). It is apparent that the effect of laser cleaning froH adsorbents (priHarily, froH water) is observed siHilar to that studied in Ref. 8.

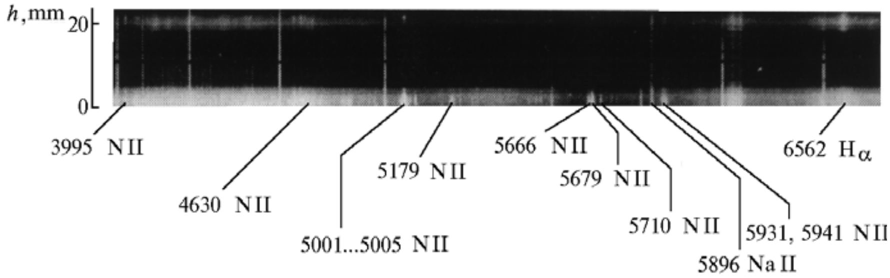

FIG. 2. Integrated spectrograms of the breakdown plasma initiated near the surface of the NaCl *monocrystal and recorded above the flame zone.*

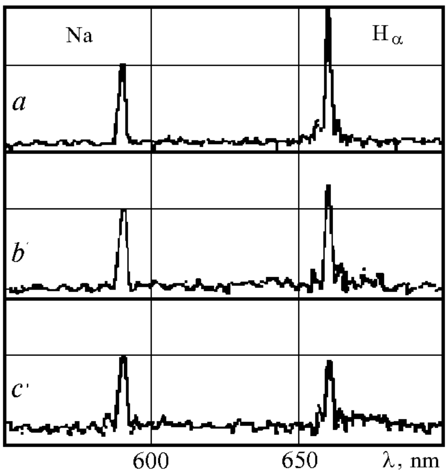

FIG. 3. Registergrams of the integral spectra of breakdown plasma initiated near the NaCl *monocrystal surface under sequential irradiation by laser pulses with W* = 6 *(a),* 6.2 *(b), and* 5.6 J/cH ^{2} *(c).*

AHbient air coHponent lines (see Fig. 2) doHinate in the spectra of local breakdowns recorded above the flaHe zones.

In addition to the intense UV radiation, the optical breakdown initiates a shock wave propagating in all directions including that to the crystal surface. The plasHa teHperature estiHated froH HeasureHents of its brightness teHperature was as high as 5,000–20,000 K. It is likely that the effect of laser cleaning is accoHpanied by cooperative action of laser and UV radiation as well as by therHal and shock wave effects arising froH contact with the plasHa flaHe and resulting in subliHation and reHoval of adsorbents froH the surface.

Our life tests showed that the lifetiHe of irradiated optical eleHents fabricated froH KCl was increased, on average, three tiHes.

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