# LASER DAMAGES OF TRANSPARENT MATERIALS AND HOLOGRAPHIC METHODS OF RECORDING

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The damages of transparent materials are made by a ruby laser of a very large power density of about $10^{14}$ W/m$^2$. The damages are provoked in a vacuum of ($p_0$=0.65mPa, and in the air p=$10^5$Pa).

Investigating the damages of the materials in vacuum and in NTP conditions, acoustic recording of incident waves in the atmosphere, induced by the interaction (i.e. a response of the sample chamber) are made. As a second technic of recording, suitable for transparent materials, the (photo-elastic) method of holographic interferometry is proposed. A possible schemes of holographic recording of the interaction and subsequent data analyze are discussed. The phenomena in the time interval between 6 μs (the regime of free generation) and 30ns (Q-switch regime) are investigated. The analyze of optical stability of the experimental set up, stability of the lasers working conditions and mechanical stability during the interaction is performed.

## INTRODUCTION

The beam profile is a very important parameter in thermic processes investigation during a laser interaction. In the processing of materials in the focal plane, the beam radius is to be determined considering the angular divergency of the beam radius. But, the theoretical assessments are not accurate. Likewise, it is difficult to estimate the beam radial distribution of the base of dimensions of the evaporated zone in materials with a low heat conductivity. For TEMoo mod, the width of the evaporated zone at the level 1/e, the characteristic dimension of the field dumping, can be taken as the beam diameter. Measurements of the beam cross-section dimensions for a complex radiation, gave even greater error. For the short focus optic the beam dimensions vary at distances of the order of the depth of the evaporated zone (1). Fluctuations of the laser system parameters which influence the interaction, depend on the laser pulse stability, energy fluctuations (caused by the power source instability) and the temporal instabilities connected with

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the laser pumping rate. They particularly affect statistical distributions of the induced material damages, with particular features due to various dynamic conditions in CW, free generation and Q-switch mode, up to the fs pulses (1-3).

The main problems in focusing are: 1) the characteristics of the laser source itself (spot diameter, divergency, degree of polarization, mode structure, radial beam distribution), 2) the focusing system parameters (mostly of the transparent optics) and 3) material parameters (coefficient of reflection, surface conditions). The choice of the focal length is predominantly determined by the technological requests to the laser system, e.g. by the specific operation that should be performed and the material characteristics. The optical strength of the used components is of a great importance, because of the great power densities that are exposed to. This is the reason why the glow must not be used in the fabrication of the components for the some wavelength intervals. The short focal length lenses can not be recommended because of the possibility of the lens damages by the evaporated material, and the appearance of great spherical aberrations. The optimal focal length for a TEMoo laser beam, can be determined according to the relation (1):

$$f_{opt} = \left(\frac{2\pi K}{\lambda} r^4\right)^{1/3}$$

where K is a constant dependent on the lens shape and n-the refraction index of the lens material; r the beam radius entering the focusing lens and λ wave length.

The optimal focal length for the maximal beam dimensions including the aperture originated from the resonator instabilities is (1):

$$f_{opt} = 0.375 d_1 \left[\frac{2.456}{\lambda} (1 - M^{-1})\right]^{1/3}$$

where M denotes a resonator magnification.

## EXPERIMENT

Experimental set up for the interaction area investigations. In the experiment with the ruby laser, the interaction area can be investigated by holographic double exposition method. First exposition is made before interaction  Second exposition is made during the interaction of the focused laser beam with the sample P (Fig.1).

In the experiment with the $Ar^{+}$-ion laser, the effects of the interaction in the vicinity of the sample surface can be recorded in the real time by the fast camera. By this method, evaporation of the samples material, plasma creation its breakdown and the creation and propagation of the torch and shock waves could be investigated.

Samples (transparent materials). The transparent samples (araldit, PMMA, plastic scintillators) are exposed to the ruby laser beam ($10^{14}$W/$m^2$) in the quartz chamber, under high vacuum conditions. Obtained damages are presented in Fig.2 and 3. Damage of the chambers walls did not appear until the evaporated samples material had not been deposited on the wall, no matter the used power density was considerably higher than quartz LIDT (table 1).

Some of investigated transparent materials are convenient for the elasto-optic investigations. The araldit sample of a cubic shape with a side transformed in a pyramid was chosen. This "model with the roof" is loaded by the compression which is done by specific manner with two supports producing the "swallow tail" pressure (Fig. 4). The unweighted sample is photographed using the presented scheme , weighted, and the obtained holographic interferent lines are taken down. However, the interferent lines are very sensitive on the weighted procedure, so the lines appear due to the surface inclination during the procedure should be removed from the picture. Used scheme is chosen in the manner which enable the monitoring of the samples volume of the order of $dm^3$ (Fig. 1). Figure 5 represents the acoustic recording of laser-material interaction. Two microphone were used: the first was placed near the sample chamber to detect the acoustic wave propagated in the air, the second one was glued on the sample chamber. The more information of optoacoustic investigations are given in (4).

## DISCUSSION

Some controversy about laser induced material damage, Laser Induced Damage Threshold LIDT (2, 3) laser system and beam control during the interaction are discussed. The holographic interferometry is proved to be one of the most sensitive nondestructive methods in the investigations of the residual stress in materials. Besides the great sensitivity (5), it gives an opportunity for the real time visual monitoring. This is particularly important in the vicinity of the critical points. LIDT definitions are somehow problematic because of the great differences in criteria in LIDT establishing (e.g. remaindering of 50% or 1/e of the component efficiency), conditions of investigated materials and the description of the LIDT (using mechanical parameters or the parameters of the dielectric breakdown). The various physical reasons for LIDT appearance can be described with several classic or quantum procedures. The LIDT provoked by the Brillouin mechanism is not related to the damages provoked by other mechanism in a regular way.

TABLE 1. Some LIDT parameters for fused and crystal quartz

| Mechanism | Power density ($10^{10}$ W/$cm^2$) |
|---|---|
| Brillouin | 1.11 (1); 0.89 (2) |
| Volume breakdown | 1.45 (1); 3.1 (2) |
| Surface breakdown | 1.95 |

(1) - fused
(2) - crystal

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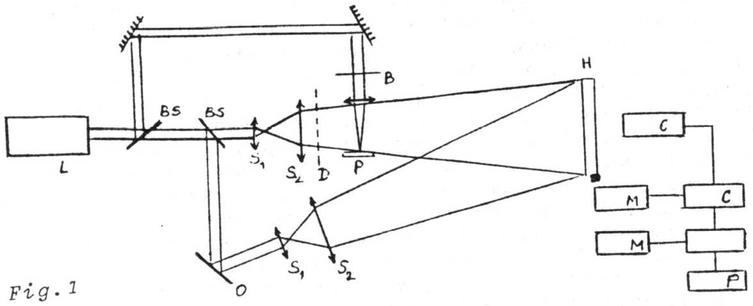

Fig. 1

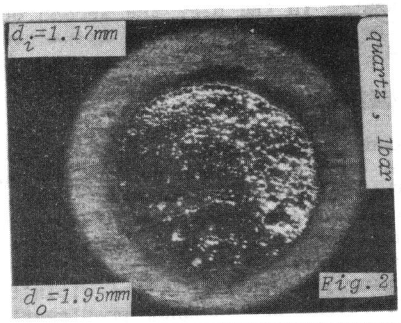

Fig. 2

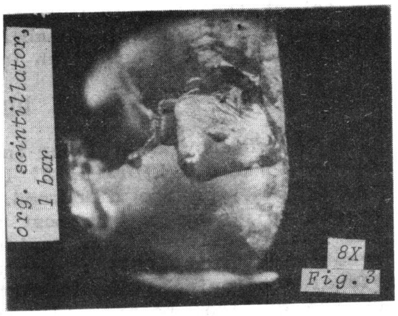

Fig. 3

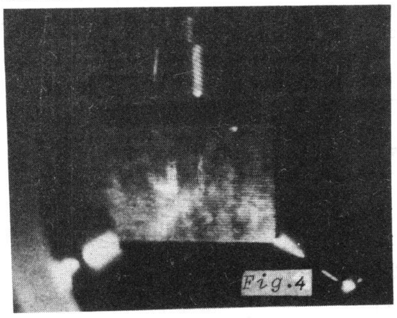

Fig.4

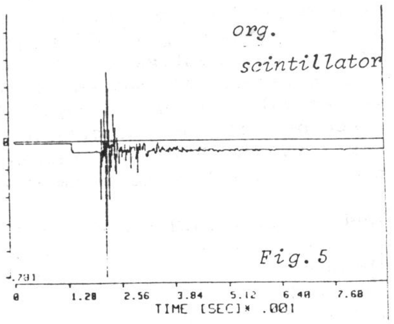

Fig. 5