Laser Drilling and Cutting in the
Thermal and Ablative Regimes - Part III

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"Laser Drilling and Cutting in the Thermal and Ablative Regimes - Part III"

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A solid state Nd:YAG laser setup producing microsecond and submicrosecond laser pulses at 1064 nm wavelength for the laser ablation experiments have been installed and upgraded.

Stable, temporarily and spatially smooth and homogeneous laser pulses in the pulse width range varied from 200 nanoseconds - 5 microseconds, with a maximum output energy value as high as 300 millijoules at a repetition rate of 1 - 10 Hz have been obtained.

The photographs showing temporal and spatial distribution of pulses generated along with the laser principle scheme are demonstrated and described.

14 June 1995

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1. Microsecond laser setup: brief description and principle of operation.

To produce high power laser pulses with a pulse width of about one hundred nanoseconds to several microseconds the laser source with an extremely long resonator was applied[1]. The length of the resonator have been extended with an optical time-delay line consisted of all-silica step-index optical fiber.

Figs. 1, 2 demonstrate the microsecond laser system principle scheme.

Fig.1. Microsecond laser master generator.

A master generator consists of a flashlamp-pumped YAG:Nd crystal rod with diameter of 6.3mm, a passive Q-switch element, an optical fiber time-delay, two matching lenses and two flat dielectric mirrors. The length of the fiber was varied from 115 meters for 4.5 microsecond pulse producing to 5 meters in the case of 150 nanosecond pulses. A 20 meter long fiber was used to obtain 1.1 microsecond pulses. To reach a high enough output energy an all silica step index optical fiber with 300 microns core diameter have been applied as a time-delay. The optical waveguide also plays an additional important role serving as a mixer of transversal and longitudinal laser modes that, in turn, leads to laser beam homogenization and prevents "hot spots" and a speckle structure appearing.

A passive Q-switch - YAG crystal plate doped with Cr⁴⁺ ions, have been selected as one of the most reliable nonlinear element providing generation of high power, stable output laser pulses. The 20 mm focus length lens is used for adjusting optical fiber and YAG:Nd rod aperture, whereas 100 mm focus length lens serves partially as a beam collimator so as provides a required value of energy density onto the Q-switch element. Varying the diameter of the beam (or energy density) it is possible to vary to some extent a pulse width as well as a temporal profile and stability of laser radiation.

The initial transmission of passive Q-switch, its position inside the laser cavity, the reflection of output mirror, and fiber length were optimized for each pulse duration to reach a maximum output energy in conjunction with maximum stability of spatial and temporal parameters of laser pulses.

Fig. 2 demonstrates the microsecond laser system as a whole.

Fig. 2. Microsecond laser principle scheme.

In order to enhance the energy of laser pulses an additional YAG:Nd amplifier with a crystal rod diameter of 6.3 mm was installed. To exclude the influence of the amplifier on the master generator operation and to prevent a positive feedback arising due to a back reflection from a target surface that results in a distortion of laser radiation parameters, an optical insulator consisted of a polarizer and a quarter wavelength plate, has been placed as it is shown at fig.2.

2. Microsecond laser output parameters: measurement techniques and results obtained.

A temporal behavior of laser pulses was checked with a high speed oscilloscope and a photodiode. A temporal resolution of the diagnostic equipment was 5 nanoseconds. Figs.3, 4, 5 show the results obtained. In all cases the temporal profile of laser pulses reveals smooth, bell-shape form. The measured (at full-width-half-maximum - FWHM) pulse durations were as high as 0.15; 1.1; and 4.5 microseconds.

Fig.3. Temporal distribution of 150 nanosecond laser pulses. Scale - 100 ns/div.

Fig. 4. Temporal distribution of 1.1 microsecond laser pulses. Scale - 500 ns/div

Fig. 5. Temporal distribution of 4.5 microsecond laser pulses. Scale - 2 microsecond/div.

To measure a spatial distribution of laser beam a CCD array with spatial resolution of 25 microns was used. The array was placed in a focal plane of an aspheric lens of 45 mm focal length (see fig.2). It is planned that this lens will be used for beam focusing in the future ablation experiments. Fig. 6 demonstrate laser pulse spatial profile near the focal point. As one can see the shape is close to the rectangular with a flat top and with no any hot spots and visible aberrations. The diameter of the focused beam is 375 microns (at FWHM).

Fig. 6. Spatial distribution of laser beam near the focal point.

The energy of laser pulses was measured with a pyroelectric energy meter and a calibrated photodiode. The output laser pulses with energy as high as 300 millijoules per pulse at repetition rates of 1-10 Hz have been obtained for 1.1 and 4.5 microsecond pulsewidths, and maximum 200 millijoules per pulse (1-10 Hz repetition rate) have been reached for 150 nanosecond pulses.

It should be pointed out that the stability and reproducibility of temporal and spatial distribution of the laser radiation so as the output energy are high enough. Thus, the pulsewidth variation from pulse to pulse is not exceeds 5 percent, and the energy stability is better than 2 percent.

3. Reference.

1. G.Muller, J. Helfmann, V.P. Pashinin, P.P. Pashinin, et al. "New alternative for laser lithotripsy: long pulse passively Q-switched solid-state laser with fiber-based resonator", SPIE Proc., vol. 2086, pp. 103 -110, 1993.