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Abstract. A new research facility for comprehensive analysis of laser-induced plasma objects equipped with high resolution devices for space, time and spectral measurements was developed. The results of combined use of laser probing and spectral analysis of metal erosion laser jets (ELJ) allowed us to propose and justify models of laser erosion of metals for various modes of exposure.

1. Introduction

Monitoring of energetic, temporal, spatial and spectral characteristics of plasma objects arising as a result of laser exposure is of great practical interest for developing high-precision laser technologies of material processing [1-3]. The main goal of this work was development of an automated hardware and software research complex equipped with high resolution devices for precision measurements in space, time and spectral domains, which enables optical diagnostics of laser-induced plasma formations.

2. Research complex for diagnostics of laser-induced plasma objects

The schematic diagram of the suggested research facility shown in figure 1 is comprised of 5 units: (I) is the unit where an acting pulse is formed and its characteristics are registered, (II) is for studying the spectral characteristics of (ELJ), (III) is for laser probing of ELJ, (IV) is for experimental data processing, and (V) is the synchronization arrangement.

Unit (I) incorporates laser (1), deflecting plates (2) and (3), pulse form recorder (4) (photo diode) and calorimeter (5).

Unit (II) is designed for high spectral and spatial resolution investigation of ELJ [4] using approaches of Laser-Induced Plasma Spectroscopy (LIPS).

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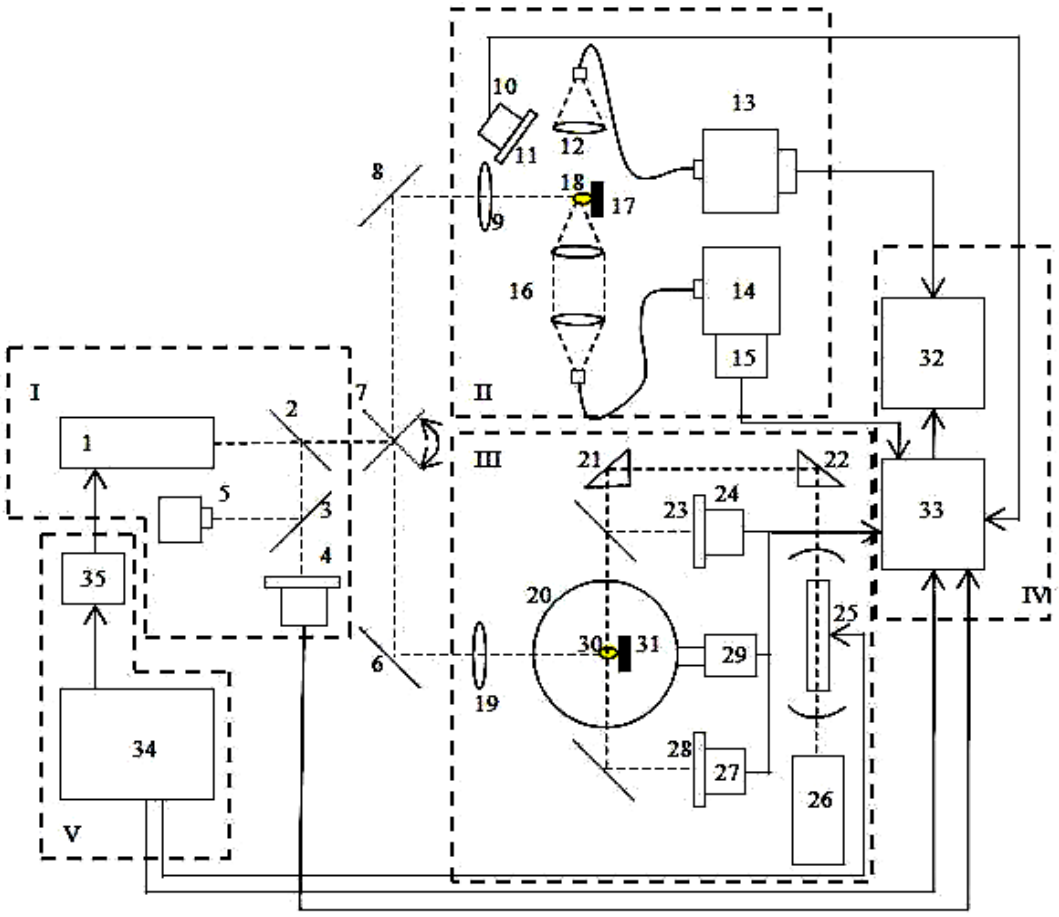

Figure 1. Diagram of the facility for optical investigation of laser-induced plasma objects. 1 – exposing laser; 2, 3 – transparent deflecting plates; 4 – pulse form recorder; 5 – pulse energy recorder; 6 – 8 – mirrors; 9, 19 – exposing radiation focusing lenses; 10 – ELP integral glow censor; 11, 23, 28 – optical filters; 12, 16 – optical systems for ELP image formation at the entrances of the spectral devices; 13 – spectrophotometer, 14 - monochromator, 15, 29 – photoelectric multiplier; 17, 31 – laser targets, 18, 30 – ELP.; 20 – integrating sphere; 21, 22 – rotary prisms; 24, 27 – probing radiation intensity detectors; 25 – probing laser, 26 – auxiliary alignment laser; 32 – portable computer; 33 - multichannel ADC; 34 – sync pulses generator; 35 – exposing laser synchronization optocoupler.

Using LIPS along with Time Resolved Laser Spectroscopy (TRLS) makes it possible to study the temporal structure of glow spectrum of plasma objects [5], which, in its turn, allows us to have a better picture of physical processes taking place in ELJ of metals as a result of exposure to laser irradiation. Investigation of dynamics of ELP integral glow can also be of practical interest [6].

To accomplish the aforementioned research tasks the facility includes spectrophotometer (MS 2001i) with a CCD acting as a light detector (13); monochromator (14) coupled with the silicon photomultiplier (SPM 10020 SensL) and photodiode (10) equipped with an interference mirror (11) (λ=1064 nm) to neutralize the effects of exposing radiation. In addition to that, the unit incorporates a pointing system (7-9) which directs the radiation at the surface of the target (17), together with optical systems (12) and (16) for imaging of ELJ (18) at the entry points of spectral devices.

Unit (III) uses laser probing of ELJ [4, 7] to examine the stages of formation and evolution of ELP. This unit contains a system for forming and targeting of probing pulse at ELJ (21, 22, 25, 26), a

targeting system (6, 7, 19), which allows to direct the exposing pulse at the target (31), as well as a system for registering scattered and absorbed components of probing radiation (23, 24, 27, 28, 29). It should be noted that in this case the light detectors are shielded with interference filters which protect them from spurious radiation and minor flares.

Data processing unit (IV) consists of a multi-channel 100 MHz digital oscilloscope 33 (B422) and a portable computer 32. The software bundle developed for the several basic modes of the facility allows automated recording, initial processing and representation of obtained experimental data.

Unit (V) includes the G200P multichannel generator of delayed pulses (34), which provides separate triggering pulses for each channel within the wide range of their durations and delays. Besides, optocoupler (35) eliminates accidental triggering of exposing laser by induced interference.

3. Summary

The optical measuring stand described in this paper provides a comprehensive study of the erosion of ELJ that occur when metal targets are exposed to high-power nanosecond laser pulses. The obtained experimental results make it possible to determine the main regularities in the formation and kinetics of liquid-drop phase of metals in near-surface region of the target under atmospheric pressure. Condensation mechanism of formation of liquid drops, originated in nanosecond laser-induced erosion torches was experimentally found and justified. The results of these studies formed the basis for new methods of metallic nanostructures formation for various purposes.

References

[1] Mirkin L I 1975 *Fizicheskie osnovy obrabotki materialov luchami lazera (Physical Foundations of Material Processing by Laser Beams)* (Moscow: MSU)
[2] Rykalin N N, Uglov A A, and Kokora A N 1975 *Lazernaya obrabotka materialov (Laser Processing of Materials)* (Moscow: Mashinostroenie)
[3] Anisimov S I, Imas Ya A, Romanov, G S and Khodyko Yu V 1970 *Deistvie lazernogo izlucheniya bol'shoi moshchnosti na metally (Action of High Power Laser Radiation on Metals)*, (Moscow: Nauka)
[4] Goncharov V K , Kontsevoi V L, Puzyrev M V and Smetannikov, A S 1995 *Instr. and Exp. Techn.* **38** 661
[5] Demtroder W 2008 *Laser spectroscopy: Vol. 2 Experimental Techniques* (Berlin: Heidelberg)
[6] Goncharov V K, Kozadaev K V and Shchegrikovich D V 2013 *J. Appl. Spectr.* **80** 395
[7] Goncharov V K, Kozadaev K V and Shchegrikovich D V 2013 *J. Eng. Phys. Thermophys.* **86** 798