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# Concept and design of a compact laser system for remote measurements by the method of laser-induced breakdown spectroscopy

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**Abstract.** A compact laser system based on a Nd: YAG laser with a wavefront self-reversal for remote analysis of substances by laser-induced breakdown spectroscopy at a distance of at least 10 m is proposed. The possibility of creating a reliable system for remote diagnostics of materials by laser-spark emission spectroscopy, including in real time, is shown.

Laser-induced breakdown spectroscopy (LIBS) is one of most promising methods for remote chemical analysis of substances in any aggregative state. A laser system for measurements by LIBS (an LIBS system) usually involves a commercial flashlamp-pumped laser with a linear cavity as a radiation source [1, 2]. A significant increase in the intensity of the plasma radiation of the substance under study and, as a consequence, obtaining a more intense analytical response in the form of a line spectrum of plasma radiation when using paired laser pulses with a tunable delay between them have been demonstrated in a series of works [3]. In this work, an LIBS system with high energy and spatial characteristics of laser radiation based on a small-size pulsed Nd:YAG laser with self-phase conjugation during the multiwave interaction in an active (amplifying) medium and passive Q-switching (PQS) is proposed for the first time. The optical scheme of the designed laser system included one active element (AE) based on a Nd:YAG crystal with dimensions of Ø 8 × 180 mm and $Nd^{3+}$ ion density at a level of 0.9 at %, eight reflecting mirrors, and a PQS based on a LiF: $F_2^-$ crystal with initial transmission varying within the range of $T_0$ = 14–17%. The transverse pumping of the AE was implemented by 16 pulsed SLM 3-2 laser diode matrices with a maximum total radiation energy $E_{pump}$ = 14.5 J and pulse repetition frequency of up to 10 Hz. The laser diode matrices were placed along the AE in four rows (four matrices in each row). The overall dimension of the cavity along the propagation axis of the laser output beam was 0.6 m [4]. The scheme of the LIBS system is presented in Fig. 1. The optical focusing scheme included a 10BE03-2-12 variable zoom beam expander (Standa) and a long-focus lens with apertures of 50 mm. The plasma radiation was collected by an optical system consisting of focusing lens 4 with an aperture of 50 mm and COL-UV/VIS collimating lens (Avantes) connected to

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spectrometer 5. The radiation was transmitted by an optical fiber with a diameter of 60 μm to the entrance aperture of the AvaSpec-ULS2048L-USB2 spectrometer (Avantes) with a spectral resolution of 1 nm. Laser triggering, synchronization of laser operation with the spectrometer, recording, and plasma spectrum processing were carried out using a proprietary software [5].

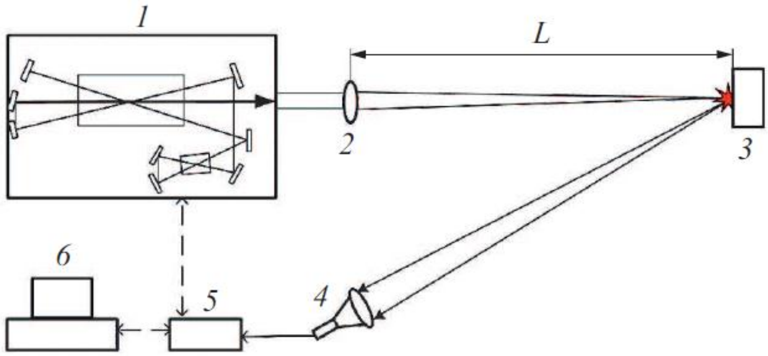


**Fig. 1.** Laser system for measurements by LSES: (1) Nd:YAG laser with self-phase conjugation, (2) focusing system, (3) sample under study, (4) radiation reception system, (5) spectrometer, and (6) PC.

The measurements by use of the proposed LIBS system were carried out in two different laser operation regimes: passive Q-switching in the mode of generating a single pulse or a train of two pulses, as well as self-Q-switching on an outer plasma mirror. The algorithm of automatic identification of the target material and type of the target material (steel, zinc, aluminium, concrete, etc.) were similar to those presented in [6]. As a result of preliminary experiments, typical LIBS spectra of materials of interest were recorded and the corresponding database was collected. The spectrum processing procedure used earlier [6] was supplemented by a series of procedures necessary for compensating the background radiation, increasing the signal-to-noise ratio, distinguishing emission bands with their identification, increasing the spectral resolution, and so on [5]. Thus, using the pulse Nd:YAG laser with self-phase conjugation provides the possibility of creating a simple, compact, and, as a consequence, reliable system for remote diagnostics of materials.

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