Measurement of laser radiation parameters by speckle interferometry

S.M. Kobtsev
Division of Laser Physics and Innovative Technologies, Novosibirsk State University, Novosibirsk, 630090, Russia
e-mail s.kobtsev@nsu.ru

***Abstract* — The article discusses the possibilities of simplified measurement of the key parameters of laser radiation on the basis of speckle interferometry and machine learning methods. It is demonstrated that the corresponding device may be designed as a compact and inexpensive laser accessory capable of replacing the entire conventional set of laboratory measurement equipment. Development of a new type of more universal accessory for characterisation of laser radiation will enable transition from the conventional concept 'laser in the lab' to the emerging advanced concept 'lab in the laser' allowing characterisation of output radiation without recourse to external specialised equipment.**

Keywords— speckle, machine learning, special reflective (or transparent) surface, characterisation of laser radiation

I. Introduction

Development of laser systems with broadly adjustable radiation parameters - including radiation wavelength and spectral width, continuous wavelength tuning range, duration and repetition rate of pulses, and so on - necessitates introduction of easier means of monitoring the radiation of such lasers. The output radiation parameters are usually monitored according to the conventional concept "laser in the lab", which implies operation of the laser in a laboratory environment and using external measurement equipment for periodic characterisation of the output radiation. Such equipment normally does not make part of the laser system and its cost frequently exceeds that of the laser itself. The present work discusses the transition from the concept "laser in the lab" to the new concept "lab in the laser" relying on speckle interferometry augmented by machine learning methods. The essence of this transition is in making the laser system self-sufficient, obviating the need of external expensive equipment for measurement of the adjustable radiation parameters

II. Setup

Fig. 1 shows schematically the layout of a universal device for monitoring of laser radiation parameters.

The gist of the method is to make a product (in this case, a laser or a laser system) self-sufficient, requiring no external (or additional) expensive equipment for characterisation of the parameters of universal radiation. Such characterisation may be performed with the aid of speckle interferometry, which is inherently possible practically with any laser radiation and whose promise will be more thoroughly elucidated in this paper. The similarity of the fundamental physical effect (interference) of this method and the traditional ways of finding laser radiation parameters (wavelength measurement [1], etc.), high (phase) sensitivity of interferometric methods provide ample grounds for implementation of this method.

This work was supported by the Ministry of Science and Higher Education of the Russian Federation (FSUS-2020-0036)..

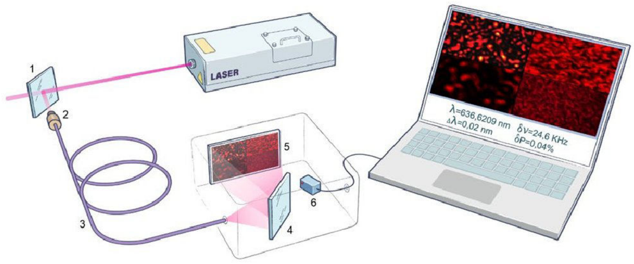

Fig. 1. Layout of the device relying on speckle interferometry and methods of machine learning for measurement of laser radiation parameters: 1 – beam splitter branching off a small fraction of the radiation, 2 – collimator guiding radiation into the optical fibre, 3 – optical fibre, 4 – diffuse surface producing speckle patterns, 5 – screen, 6 – camera. Instead of 5 and 6, a photosensitive image acquisition matrix may be used directly.

Application of machine learning methods for processing of speckle images is called forth by two major factors. The first of them is that speckle images may produce big data, thus making methods of intelligent machine analysis efficient. The second factor is absence of an established analytical dependence of the speckle patterns upon the sought for radiation parameters that makes conventional methods inefficient. Employment of a special reflective (or transparent) surface producing speckle images may simplify their 'deciphering' and improve accuracy of measurement of the sought for laser radiation parameters.

Extraction of information from the interference pattern becomes significantly easier in case the profile of the rough surface or of the refractive index across a transparent medium is known. Furthermore, this profile should be optimal from the viewpoint of the best achievable accuracy of radiation parameter calculation. One of the initial requirements to the inhomogeneity profile is that of multiple scales of interference, analogous to the presence of interferometers with different thickness, as it occurs, for example, in some radiation wavelength meters.

[1] Roopam, K. et al. "Deep learning enabled laser speckle wavemeter with a high dynamic range," Laser Photonics Rev., v. 14, 2000120 (2020).

2022 International Conference Laser Optics (ICLO) | 978-1-6654-6664-6/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICLO54117.2022.9840102