**NON-INVASIVE BIOMEDICAL RESEARCH AND DIAGNOSTICS ENABLED BY INNOVATIVE COMPACT LASERS**

Rafailov E.U.

Rafailov E.U., Professor, Head of Optoelectronics and Biomedical Photonics Group, Aston Institute of Photonic Technologies (AIPT), School of Engineering and Applied Science, Aston University, Birmingham, UK, [e.rafailov@aston.ac.uk](mailto:e.rafailov@aston.ac.uk)

**Abstract.** In the last decades, progress in the development compact of laser sources has brought to science and industry an enormous number of new applications. Previously, such lasers were mostly utilised in the communication and other industries. However, now such laser sources are becoming adopted in biomedicine and related fields. The recent progress on the development of novel compact laser sources generating light across broad spectral ranges in CW and ultra-short pulse regimes, were presented in this work. Also some of the most promising applications were reviewed where such laser sources are being used in biophotonics, particularly focussing on multi-photon imaging and cancer diagnostics and photo treatment.

**Keywords:** compact laser, non-invasive diagnostics, multifunctional laser diagnostics, microcirculation, tissue oximetry, autofluorescence

For over half a century, laser technology has undergone a technological revolution. These technologies, particularly semiconductor lasers, are employed in a myriad of fields. The use of lasers in biology and medicine is based on the exploitation of a wide range of phenomena associated with the various manifestations of biological objects with light interaction. The unique properties of the laser beam opened opportunities of its application. Three effects are the basis of the application lasers in various fields of surgery, therapy and diagnosis. Photodestructive effect impact, in which the thermal, hydrodynamic and photochemical effects of light cause tissue destruction. This kind of interaction may be observed in laser surgery, namely photodestructive, photophysical and photochemical effects and nonperturbing impact. Photophysical and photochemical effects, in which the light absorbed by biological tissues excites the atoms and molecules, causing photochemical and photophysical reactions. These effects often find applications as therapeutics. Nonperturbing impact, when biotissue does not change its properties during the interaction with light. These are effects such as scattering, reflection and penetration. This type is employed for diagnostics.

Optical medical diagnostics, one of the emerging areas of laser application, are on the forefront of application around the world. Optical methods of non- or minimally invasive bio-tissue investigation offer significant advantages over alternative methods, including rapid real-time measurement, noninvasiveness and high resolution (guaranteeing the safety of a patient). These advantages demonstrate the growing success of such techniques.

Non-invasive optical approaches can solve many problems in diagnostics. Biophotonic applications of systems based on compact semiconductor lasers range from diagnostics and imaging applications such as optical coherence tomography, fluorescence lifetime imaging, tissue oximetry, diffuse optical imaging, THz imaging or laser Doppler imaging, to treatments. For example, in dermatology, ophthalmology, gynaecology, gastroenterology and neurosurgery, optical methods are promising for diagnosis, localisation and treatment of malignant neoplasms, photodynamic therapy of various diseases, mammography and imaging of the skin and internal organs. Transscleral photocoagulation of tissues in the eyeball (ciliary body, retina, etc.) is widely used in ophthalmology for the treatment of glaucoma, retinal detachment and other diseases. Optical methods are used to monitor the functional activity of the brain, heart, vascular system function, determining the rate of blood flow and lymph flow, blood volume in tissues and its degree of oxygenation. Modern biophotonic techniques offer many potential technological advances, such as diagnosis and prevention of diseases; identification of chronic disease risk factors; earliest stage disease diagnostics; health monitoring.

While the non-invasive techniques provide detailed structural and biochemical information, they generally offer less quantitative information related to the clinical diagnostics. Individually, in some cases, methods have been limited by the lack of efficiency. For example, recorded fluorescence methods strongly depend on the absorption (haemoglobin, oxyhaemoglobin, melanin etc.) and scattering (microstructure properties of biological tissues’ depth and surface, level of blood supply, water content) parameters. The capacity for diagnoses may be significantly improved by combining different methods and techniques. The advent of easily accessible, compact semiconductor based lasers makes the combination of such methods and techniques, previously large and expensive, possible.

For combination using of different diagnoctics methods through the dynamic development of optical spectroscopic methods used in clinical practise gave birth to multifunctional laser non-invasive diagnostic systems (MLNDS). Based on results of experimental studies the potential of MLNDS at providing clinicians with useful, easily understandable information on the condition of patients were revealed. Specifically, the ability to simultaneously record and combine a wealth of information, rather than carry out many individual analysis using different spectroscopic tools and technologies. While real time human measurements will always vary from tissue to tissue, organ to organ or person to person, such multifunctional analyses allow for the minimisation of errors that stem from individual use of the described methods. A more accurate picture can be painted using the combination of methods and analytical techniques.

In the next few years, non-invasive technology will have revolutionised medicine. The future prospects for multifunctional laser non-invasive diagnostic systems are the development of high performance compact laser sources that, at a low cost, will individually or in hybrid format, cover virtually any spectral band required for laser diagnostics.

In the future, diagnostics will migrate from the clinic to the home and workplace where advanced technical solutions integrating multiple scientific advances will provide early warning of disease risk and onset. It is easy to imagine major global diseases such as CVD, cancer and type 2 diabetes being detected and diagnosed much earlier, more conveniently and at a lower cost than is possible today.

Modern photonics based systems can be minimised down to watch size and can monitor human health condition, while wirelessly sending this information to your PC and practitioner. Thus, wearable devices and ever-improving smartphones can serve as the hub for new diagnostic and treatment technologies. Therefore, anyone, anywhere (working or gym), at any time (during exercise or sleep) can obtain the necessary information about their condition.