PERSPECTIVES IN OPTOELECTRONICS
Present and Future in INOE

Roxana Savastru, Gabriela Pavelescu, Roxana Radvan
National Institute of Research and Development for Optoelectronics INOE 2000
inoe@inoe.ro, 409 Atomistilor Street, Magurele, Ilfov County, Romania

ABSTRACT: Optoelectronics, area which enjoys global strategy for the coming decades, covers an extremely wide field, with vague borders. It comprises everything and anything related to the instrumentation that emits, modulates, detects and transmits the light. Optoelectronics and photonics encompass multiple technologies underpinning numerous applications from consumer, entertainment and computing, homeland security, industrial markets and to defence. Among the research activities dedicated to developing new materials for optoelectronics and optoelectronic devices for nurturing them through different applications, in INOE we are focused on using lasers beam in the various fields of optoelectronics. Our research targets many areas related to the quality and improvement of human life: from ground to air, human to environmental health, economics to cultural heritage, we develop laser-oriented applications.
KEY WORDS: optoelectronics, laser application, road infrastructure, remote sensing, medicine, cultural heritage

1. INTRODUCTION

The mission of the National Institute for Optoelectronics is to develop materials for optoelectronics and optoelectronic devices for industrial applications, art restoration, environmental monitoring/remediation and beyond. Our main activity is the advanced research in the fields of physical processes, specific techniques and complementary systems that emit, modulate, transmit and receive optical radiation, pointing toward applications in optoelectronics.

Experimental and theoretical activities are focused on the following research directions:

- Optoelectronic methods and techniques for cultural heritage restoration/conservation;
- Advanced techniques of environment assessment;
- Advanced materials with applications in optoelectronics;
- Surface processing by vacuum and plasma advanced technologies;
- Analytical instrumentation and advanced methods for analysis - Environmental Analysis Laboratory - ISO/ 9001/2008;
- Constructive and technological engineering – lasers, laser and fiber optics devices.

The staff formula of INOE was build up to create a dynamic research group able to activate in the fundamental and applicative research for environmental, civil engineering and health applications, with the main goal of improving life quality in all its forms.

The rapid development of the optoelectronics field has led to the improvement of laser sources and to the diversification of their range of uses. Lasers are used in practically every aspect of life: forensic science, medicine, environment, nuclear science, electronics, industry, military etc. Most research in INOE is based on laser and fiber optics devices, orientated towards applications in artefact evaluation/restoration, medicine, environment, road infrastructure, defense and many other areas.

We are constantly trying to improve our research infrastructure, by adding multipurpose equipment to serve the needs of all departments, such as the NanoSAM LAB S Scanning Microscopy System - multiple users research base.

2. OPTOELECTRONICS APPLICATIONS

2.1 Cultural heritage

Artworks and documents of historical interest, excepting natural ageing processing, are affected by environment physical (temperature and humidity) and biological factors (biodeteriogens), and by human (pollutant releases) impact and therefore modified over the time. The knowledge of the behavior of artworks materials under thermal stress or humidity variations might help to understand how these factors accelerate and affect the deterioration of an artifact. The new demands coming from restorers and specialists dealing with cultural heritage preservation practice lead us to develop researches regarding advanced techniques for monitoring – investigation – diagnosis – intervention and post monitoring addressed to various categories and materials (stone, pigments, paper, parchment, wood etc.). Important results were obtained in laser cleaning, air quality control and microclimate monitoring, investigation methods, remote fast response techniques, remote controlled instrumentation development. Laser cleaning technique was promoted in Romania by INOE, through the Centre of Excellence "CERTO", which is involved in campaigns for diagnosis and restoration of numerous cultural sites belonging to cultural heritage, in Romania and abroad [1-3].

Figure 1. Laser cleaning on mural painting and stone

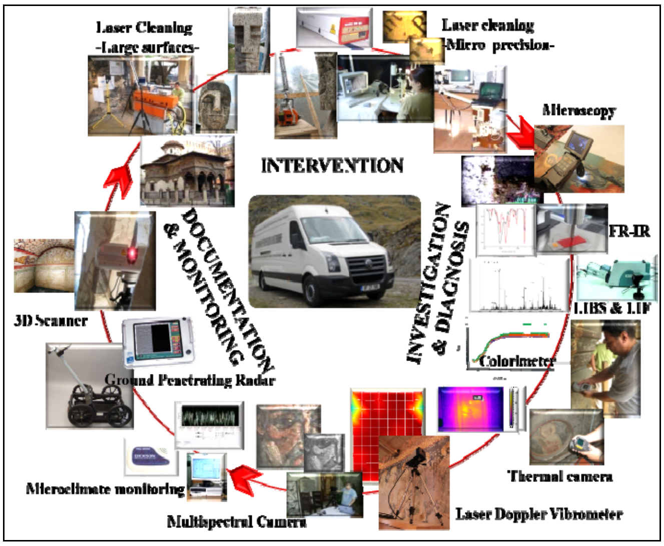
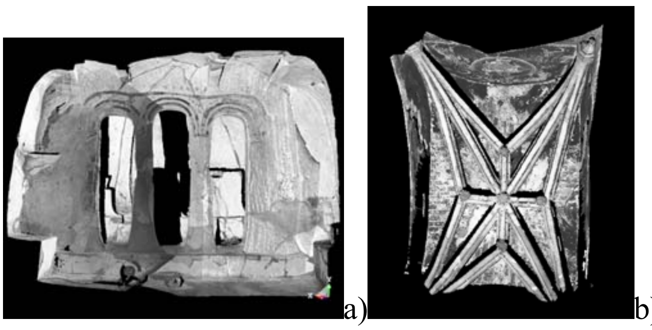


Figure 2. ART4ART - Mobile laboratory for monitoring, investigation and intervention

One of the most important criteria applied in the instrumentation development is the involvement of non or micro invasive techniques (like LIFS and LIBS), no sample collection and preparation (particularly on site available instrumentation), with fast response for effective diagnosis and intervention decision [4].



a) b)

Figure 3. Digital-models of a) Murfatlar Caves Ensemble and b) Balinesti Church – Gothic porch

Development of open-laboratory for on-line access to infrastructure (for different purposes: training, education, common experiments, expert counseling etc.) and of open-restoration workshop (by mobile laboratory) for on-site monitoring of certain parameters, campaign duration prolongation (extended effective working time) are representative for the achievements we can be proud of.

2.2 Road infrastructure

One of the most important objectives to be met by existing transportation systems is the security. Differences in vertical direction, between the theoretical surface defined by the designer and the real surface of the road, can often appear. These irregularities affect the uniformity of a road, which is one of the main functional characteristics of the road structures. The studies concerning the comfort, circulation safety and the dynamic action of the loadings with which the vehicles stress the running surfaces with uniformity defects, revealed the necessity to identify the irregularities whose wavelengths are situated between 0.5 m and 50 m. In response to this requirement, INOE has developed a new solution for measuring the quality of the road based on a pioneering approach.

The proposed system allows, for the first time, the simultaneous measurement of longitudinal and cross sections of roads with a specially equipped vehicle that moves at normal speeds on the road and having a low cost infrastructure. This approach represents a significant advantage, as it eliminates the need of a reference level. Furthermore, it improves measurement accuracy by providing solutions to eliminate errors that would otherwise result from the moving vehicle dynamics.

Figure 4. Equipment for the road longitudinal and transversal profile testing

INOE was involved in elaboration of the method and equipment for testing the longitudinal and transversal profiles of roads. Our staff also developed a mobile data collection system designed to collect measurement data about objects, features, structures and landmarks located along highways and roadways, for planning, managing and maintenance (it measures heights, widths, and depths of objects, as well as offsets from the center or edge of the road, and spatial location, using GPS and inertial navigation).

2.3 Remote sensing

Earth's atmosphere is of crucial importance, without it life on earth would be impossible. Beside this, it protects us from ultraviolet sun rays and meteorites.

In the last decade, INOE's Remote Sensing Department, which is part of the Romanian Atmospheric Research 3D Observatory (RADO), has gained significant expertise in using remote sensing techniques to study the Planetary Boundary Layer and the Free Troposphere.

Figure 5. Remote Sensing techniques for environmental study

Over the years, using both national and international funds, the Remote Sensing Department was endowed with synergistic state-of-the-art equipment. The laboratory comprises passive remote sensing (e.g. Microwave Radiometer, Sun Photometer), active remote sensing (e.g. several Lidar systems, ozone DIAL, DOAS) and in situ sampling instruments (Nephelometer, Aethalometer, Aerodynamic Particle Sizer, Particulate Matter Gravimetric Sampler, Gase Point Monitors). While in situ instruments provide information on local pollution at ground, remote sensing instruments (either active or passive) are mostly useful to study long-range transport of pollutants, radiative effects and their impact on climate change.

LIDAR (LIght Detection And Ranging), the most modern technique used to characterize atmospheric constituents and processes in the upper atmosphere, was first used in Romania in 2005, at INOE [8,9].

Figure 6. Romanian Atmospheric Observatory/ Night measurements

INOE's Lidar systems can be used to study the planetary boundary layer (PBL), air quality and long-range transport. We also study the climatology of short lived atmospheric species by measuring and analyzing optical and microphysical properties of tropospheric aerosols (volcanic ash, Saharan dust, biomass burning, urban) as vertical profiles in their temporal dynamics with the purpose of identifying their short term impact on climate. An important result was the detection of volcanic ash coming from the eruption of Eyjafjallajökull volcano on April 14th, 2010 [10]. This eruption affected economic, political and cultural activities in Europe and across the world.

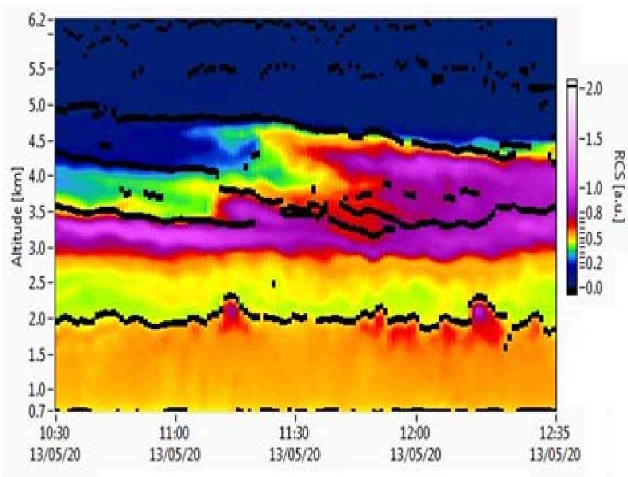


Figure 7. Dust event detected using RALI system May 20th 2013, Magurele, Romania (44.35 N, 26.03 E)

The Remote Sensing Department in INOE is a contributing station to EARLINET (European Lidar Network), AERONET (Aerosol Robotic Lidar Network), MWRNET (Microwave Grounbase Radiometers Network), EUSAAR (European Supersites for Atmospheric Aerosol Reserach), and consequently to the integrating European network ACTRIS (Aerosol Clouds and Trace gases Research Infrastructure Network). Our datasets are regularly submitted to the ACTRIS data portal, and open to the international scientific community.

As a continuous development and transfer of know-how, Romanian Atmospheric research 3D Observatory welcomes students and young researchers that choose to prepare their master and PhD thesis at our facility. They can find here a great and unique data repository, a dedicated team of scientists to exchange expertise, and a well-instrumented facility which promotes high-tech innovation.

2.4 Materials for optoelectronics applications

The microelectronics and the related optoelectronics revolution of the past few decades became an integral part of our daily life to the point where it is taken for granted, and the consumer is expecting more for less. The still omnipresent silicon is increasingly accompanied by new materials with selective properties, which closely follows the needs of the foreseen application. The research activities aiming for the development of new optoelectronics materials comprise thin films design, synthesis of thin films by PVD (methods such as ion assisted magnetron sputtering, cathodic vacuum arc and pulsed laser deposition) and sol-gel methods, as well as bulk materials. Their properties are investigated using elemental, structural, morphological, as well as electrical, mechanical and optical characterization.

The specific materials research covers studies on: InN based semiconductors with tunable band-gaps, novel photonic materials as bulk and thin films. Also, technologies were developed for: tunable band-gap InN alloy thin films; nanostructured thin films for high-temperature solar collectors; highly reflective mirrors for EUV lithography; optical sensors; micro strip line structures on BST films and on magnetic nanowire structures. Other valuable results were obtained, as by-products of the main activity in the optoelectronic domain, by taking advantage on the existing know-how: biocompatible coatings [11,12], hard coatings for various industrial applications [13,14] (automotive industry, electric energy co-generation, etc.).

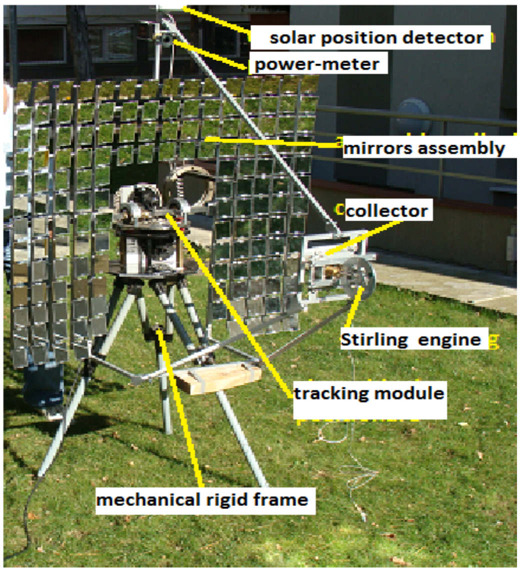


Figure 8. Small scale demonstrator of a solar-thermal system with a Stirling engine

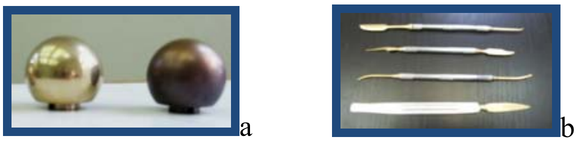


Figure 9. (a) Biocompatible coatings (b) Coated tools

PLD technique was used to obtain thin films on silicon wafers, with application as planar waveguides (from Nd-doped phosphate glasses) and temperature sensors (from CdSe-doped phosphate glasses) [15, 16].

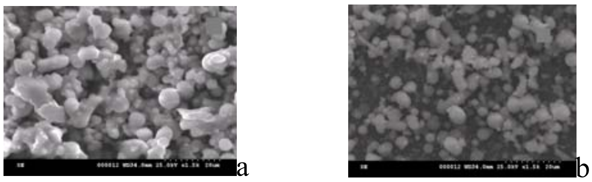


Figure10. SEM images for thin film obtained by PLD (a)Nd-doped phosphate for planar waveguides (b) CdSe-doped phosphate glass thin film for temperature sensors

A method for building photonic structures in amorphous chalcogenide films has been developed and a femto-second Ti:Sapphire laser has been used in photonic crystal registration [17, 18].

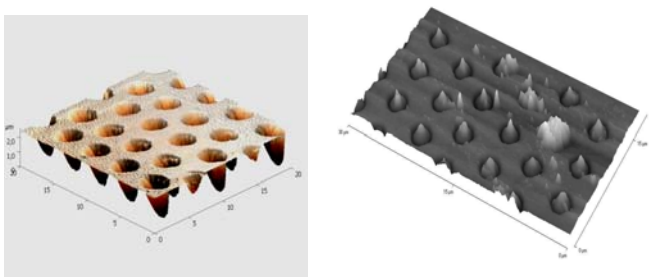


Figure 11. Direct Laser Writing of 2D photonic crystals with positive (a) or negative (b) selective etching

Numerical simulation performed on these photonic configurations showed that the obtained chalcogenide structures could be efficient for operation in the infrared range around several micrometers wavelength.

2.5 Medicine

Based on the interaction of laser radiation with the biological tissues new optical diagnostic and therapeutic methods were developed, together with some devices dedicated to surgery. The research activities were interdisciplinary, but concentrated on biomedical physics and biomedical engineering and comprise theoretical and experimental studies in the fields of optical properties of biological tissues and photochemical effect of the laser radiation on cellular and tissue level.

Innovative medical diagnosis methods for the early, non-invasive, accurate detection of skin pre-cancerous and cancerous tumors employing optospectral techniques were developed: fluorescence spectroscopy (based on the intrinsic skin fluorophores), reflectance and optical coherence tomography [19, 20].

Figure 12. Laser system developed within our team

Important results were obtained by photodynamic inactivation method of Gram-positive and Gram-negative contaminated open wounds using coherent light radiation.

Researches for new instruments for medical application were finalized: a surgical instruments (Biolaser) [21], based on the photo disruptive effect produced by the short pulse laser radiation for the posterior capsule perforation in case of opacity after an artificial crystalline transplant and a surgical Er:YAG laser device for contactless blood sampler (Laserprobe).

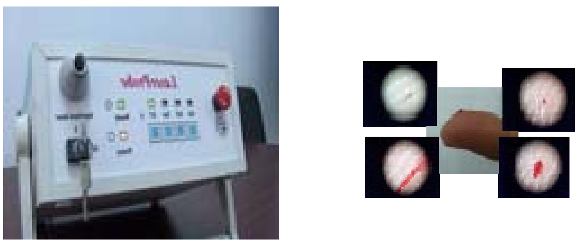


Figure13. Laserprobe- contactless blood sampler

Figure 14. Surgical device: Biolaser

3. CONCLUSIONS

The rapid technological advances in the field of optoelectronics have allowed us to diversify our range of activities. The research developed within INOE at the moment covers a wide variety of areas, including optical design, bulk and thin film optoelectronic materials, optical testing and measurement, optical engineering, photonics, and lasers. We focus our skills on application driven experiments in artefact evaluation/restoration, medicine, environment, road infrastructure, industry, energy and defense.

In the future we aim to develop advanced researches addressing a complex range of applications. These include methods to design and develop innovative materials for high-speed optical switches; conversion, utilization and efficient management of solar energy; plasmonic structures for sensors; expert systems for environmental monitoring and investigation of three-dimensional atmosphere; hyperspectral imaging in the diagnosis of medical and clinical research; advanced methods and techniques for cultural heritage investigation and restoration, including in situ archeometry for archeology.

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