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Novel laser-based photothermal methods of chemical analysis

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Abstract — University of Nova Gorica (UNG) provides access to knowledge, high quality education and incorporates nine different main research areas. One of them is covered by the Laboratory for Environmental Research which conducts basic and applied research in different areas of environmental sciences such as the investigation of photochemical and microbial degradation, and transport of pollutants in the environment; the development of laser-based methods, bioanalytical methods, and ecotoxicological tests for the identification and determination of toxic compounds and their effects on the environment; the development of new materials for applications in environmentally friendly technologies as well as the research in molecular biology and neurobiology. All in all, the main stream of our scientific work in TRANS2CARE project will be related to novel laser-based photothermal methods of chemical analysis coupled to bioanalytical assays and flow injection analysis.

Index Terms — Laser-based analytics, thermal lens spectrometry, flow-injection analysis, bioanalytical methods, chromatographic techniques

1 UNIVERSITY OF NOVA GORICA

Predecessor of the University of Nova Gorica (UNG) was the Faculty of Environmental Sciences, which was the first international postgraduate school in Slovenia. The Faculty had been founded on 24 September 1995 with an agreement from the Council of the Republic of Slovenia for Higher Education of 12 July 1995. It began operating in the 1995/96 study year. The founders of the Faculty were the Municipality of Nova Gorica and the 'Jožef Stefan" Institute from Ljubljana. The Faculty was reorganized into the Nova Gorica Polytechnic in 1998. UNG became a university institution in 2006 founded by Municipality of Nova Gorica, Municipality of Ajdovščina, the 'Jožef Stefan" Institute and the Research Center of the Slovenian Academy of Sciences and Arts

from Ljubljana. Currently UNG offers a broad range of academic programs - seven undergraduate programs, five second level programs (Master's), and seven third level programs (Doctoral). UNG has got 144 employees of whom 91 are Doctors of Science (80 of them are University professors), and 17 are young researchers (Ph.D. students). Over 32% of them are foreign scientists.

1.1 Research departments

The research activity at UNG is carried out in five research laboratories (Laboratory for Astroparticle Physics, Laboratory for Multiphase Processes, Laboratory of Organic Matter Physics, Materials research laboratory and Laboratory for Environmental Research), three research centers (Centre for Atmospheric Research, Centre for Systems and Information Technologies, Wine Research Centre) and one Research Institute (Institute for Cultural Studies). The Laboratory for Environmental Research, which will take part in TRANS2CARE project, is composed of five research groups focusing on: Organic substances in the environment (monitoring, transformation and effects), Materials for (photocatalysis) environmental applications, Molecular biology and biotechnology, Modeling of natural processes in forests, Assessment of environmental changes and Laser-based analytical methods. The latter group will be mostly engaged in TRANS2CARE project.

2 ACTIVITIES AND ROLES IN TRANS2CARE PROJECT

2.1 Laser-based methods for chemical analysis and characterization

Research related to laser-based methods for chemical analysis and characterization includes development of laser-based spectroscopic methods for qualitative and quantitative determination of various compounds present in environment, food and for studies of various chemical and biological processes. Highly sensitive novel analytical methods are being developed using thermal lens spectrometry (TLS) [1] coupled with bioanalytical techniques (acetylcholinesterase – AChE [2], transglutamninaze, and ELISA bioassays [3-4]), flow injection analytical (FIA) systems [5-6], liquid chromatography [5-6], or microscopic TLS (TLM) (shown on Fig.1) as detection technique for lab-on-a-chip chemistry and study of processes on microspace and in microfluidic systems [7]. Photothermal beam deflection spectrometry [8] is utilized to study thermal and optical properties of thin nanofilms of photocatalysts and organic semiconductors for photovoltaic cells as well as for carbon nanomaterials. Newly developed methods, which offer sensitivities over two orders of magnitude superior to those of conventional transmission mode spectrometric techniques were successfully applied for determination of various toxic compounds such as pesticides, allergens, biogenic amines, heavy metals or their species, and recently toxins, as well as essential and beneficial compounds like for example carotenoids, anthocyanins, and other physiologically relevant compounds (i.e. bilirubin) in foodstuffs, as well as in environmental and biological samples [9-10]. Recent applications include TLS detection of metal nanoparticles and exploitation of FIA-TLS for determination of toxic silver ions (Ag^{+}) [11].

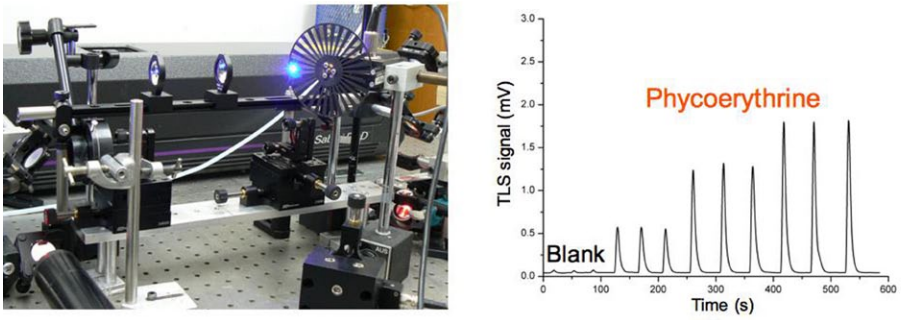

Fig. 1: Picture of a TLS microscope constructed at UNG by dr. Mingqiang Liu (left) and a sequence of TLS signals recorded by UNG PhD student Ambra Delneri during detection of phycoerythrine from cyanobacteria by the FIA-TLS technique (right) (triplicate injections of 200 µL samples: 5, 10, and 15 mg/mL).

2.2 Aims in TRANS2CARE project

The scope of our scientific contribution in TRANS2CARE project is the development of novel state of the art methods based on TLS detection in liquid flows such as in the case of high performance liquid chromatography (HPLC), capillary electrophoresis (CE), ion chromatography (IC), and FIA. These systems will enable the determination of various compounds (egg. free bilirubin, anthocyanins, glutene-derived peptides, and virus-like proteins) that might be in research focus of other TRANS2CARE partners. In addition, TLS itself will be offered as detection technique for already available bioanalytical assays such as ELISA, or those being developed by other project partners, which lack sufficient sensitivity. The research will focus also on applications of microscopic TLS relying on bioassays in combination with flow injection analysis on micro-chemical chips [4]. Such combinations provide ultra-high sensitivity, high sample throughput, reduced operational costs, simplicity and high reproducibility. It is also our aim to provide conditions for high quality training of young scientists, those employed by TRANS2CARE, as well as PhD students conducting research in fields related to this project, by enabling intensive contacts and exchange of expertise within the project consortium.

3 CONCLUSIONS

With an interdisciplinary approach and intensive collaboration of UNG with partners having expertise in fields other than analytical chemistry, TRANS2CARE project is expected to provide a stimulating environment, infrastructural conditions and opportunities for the development and application of novel state of the art analytical methods for the determination of various substances relevant in biomedical research and diagnostics. Other sectors beyond the scope of TRANS2CARE such as food quality and safety, environmental protection and others, shall also benefit from the outputs of the project. Finally, the industrial sector producing medical diagnostic tools shall benefit by the results of research conducted within the project and knowledge

transfer as well as by the availability of new highly trained young experts.

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