European University Alliance for Global Health
Lasers in Medicine and Life Sciences

EUGLOH summer school

Lasers in Medicine and Life Sciences 7

5th—9th July 2021

Organised by the **University of Szeged** | **Hungary**
with invited speakers from member universities of the **EUGLOH** alliance

- **Ludwig-Maximilians-Universität München** | **Germany**
- **Lund University** | **Sweden**
- **Universidade do Porto** | **Portugal**
- **Université Paris-Saclay** | **France**

and other distinguished European universities and research centres

Times are given in CET

Newsboards, fora, tests and other interactive tools are available in CooSpace

Programme v1

Monday, 5th July 2021

Opening and welcome		
▸ 9^{00}–9^{15}	**Márta Széll** • **University of Szeged** | **Hungary** • *Welcome by the vice-rector for strategic planning* **Ferenc Peták** • **University of Szeged** | **Hungary** • *Introduction by the organisers*	YouTube
Foundations		
▸ 9^{15}–10^{45}	**Katalin Varjú** • **ELI-ALPS** | **Hungary** • *High-energy and short laser pulses*	YouTube
Microcirculation imaging		
▸ 11^{00}–11^{45}	**Ferenc Bari** • **University of Szeged** | **Hungary** • *What did we learn about microcirculation using lasers?* Over the past decades, there has been a steady growth in microvascular research involving various forms imaging of microvasculature of various organs and tissues. In our laboratory, we have been exploring cerebral and skin microcirculation with a broad spectrum of optical methods including intravital microscopy, laser Doppler flowmetry and laser speckle contrast analysis, etc. Understanding the microvasculature is vital in tackling fundamental research questions as well as in understanding the effects of disease progression on the physiological well-being of an individual. We have been using animal models for hypoxic brain injuries and analyse blood flow changes in young and old brains with multimodal optical imaging systems. In this talk, we discuss the recent advances made and applications in the field of microcirculation imaging.	YouTube
▸ 12^{00}–13^{00}	**Lunch break**	
▸ 13^{00}–13^{45}	**Martin Leahy** • **National University of Ireland, Galway** | **Ireland** • *Tissue optics and microcirculation imaging*	YouTube
▸ 14^{00}–14^{45}	**Discussion** (moderated by **Ferenc Bari** and **Katalin Varjú**)	YouTube
	Social programme	

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Tuesday, 6th July 2021

Lasers in endoscopy

▶ 9^{00}–9^{45}

Tomáš Čižmár • **Friedrich-Schiller-Universität** | **Germany** • *Holographic endoscopy for deep-tissue in-vivo imaging*

Progress in the domain of complex photonics enabled a new generation of minimally invasive, high-resolution endoscopes by substitution of traditional lens-based imaging pathways with a holographic control of light propagating through apparently randomising multimode optical waveguides. This form of endo-microscopy became recently a very attractive way to provide minimally invasive insight into hard-to-access locations within living objects.

I will review our fundamental and technological progression in this domain and introduce several applications of this concept in bio-medically relevant environments.

YouTube

▶ 10^{00}–10^{45}

Darine Abi Haidar • **Université Paris-Saclay** | **France** • *Multimodal non-linear endomicroscope for intraoperative real-time brain imaging*

Standard of care in the management of brain tumours primarily consists of achieving maximal safe resection, while preserving eloquent brain regions. To date, diffusive tumours are still elusive to the surgeon and are the main cause of recurrence. We have addressed this critical need by developing a multimodal nonlinear endomicroscope that allows real-time optical biopsy. It will provide immediate information for diagnostic use without removal of tissue and will assist the surgeon in forming the optimal strategy for resection. Parallel to the instrumentation development, we are currently improving our understanding of the various optical features measured by multimodal optical imaging pertaining to different biomolecules.

YouTube

Laser spectroscopy

▶ 11^{00}–11^{45}

Sune Svanberg • **University of Lund** | **Sweden** • *Laser spectroscopy applied to the environmental, ecological, agricultural and food safety areas*

Laser spectroscopy is a powerful enabling technique, which allows real-time, non-intrusive diagnostic capability in wide areas of applications. Based on the speaker's experience, examples from the environmental (air and water pollution), ecological (flying disease vectors), agricultural (pests, eutrophication) and food safety areas (packaging integrity) will be given. From a technological point of view, these applications are pursued in a very similar way as in the laser-based medical-diagnostics area. The importance of inter-disciplinary research inducing cross-fertilisation between fields is stressed.

YouTube

▶ 12^{00}–13^{00} **Lunch break**

▶ 13^{00}–13^{45}

Katarina Svanberg • **University of Lund** | **Sweden** • *Applications of laser spectroscopy to meet challenges in medicine*

Laser-based spectroscopic techniques can be used in the detection and therapy of human diseases. A worldwide challenge is the increasing incidence of cancer, predicted to double by the year 2040. Another alarming situation is the rapid development of antibiotic resistance. Does laser spectroscopy have any possibility to meet some of these alarming challenges affecting the whole world? Examples from oncology, orthopaedics and food safety for health will be discussed.

YouTube

▶ 14^{00}–14^{45}

Emilie Krite Svanberg • **University of Lund** | **Sweden** • *Lung monitoring using laser spectroscopy*

Monitoring of lung function in critically ill patients is of major importance, also emphasised by the novel SARS-Cov-2 pandemic. Laser spectroscopy has the potential for in-situ monitoring of lung gases. Encouraging results have been obtained in newborn infants and in animal models. Prospects for extending the techniques for larger children and even adults will also be discussed.

YouTube

Social programme

Wednesday, 7th July 2021

Ultrafast laser spectroscopy

▶ 9^{00}–9^{45}

Gerard Baldacchino • **Université Paris-Saclay** | **France** • ***Enhanced photoionisation sensitivity of DNA explained by strand molecular sequences – Ageing consequences***

This talk introduces how low-energy photoionisation of identified DNA strands is under discussion lying on the chemical structure and internal relaxation of excited states. We talk specifically about G-quadruplex structures which are sited in chromosome-telomeres. Damage induced UV ionisations are possibly a cause of ageing precocity. Most of the discussion is based on experimental results obtained by transient absorption spectroscopy in the nanosecond time range.

YouTube

▶ 10^{00}–10^{45}

Petar H Lambrev • **Biological Research Centre, Szeged** | **Hungary** • ***Ultrafast two-dimensional electronic spectroscopy***

Two-dimensional electronic spectroscopy (2DES) is an experimental technique that has rapidly evolved for the past ten years into a powerful tool for studying ultrafast photophysical processes. This lecture introduces the fundamental principles and technical implementation of the method along with a few examples of how it can be used to study excitation energy transfer (EET) in photosynthetic light-harvesting complexes.

In photosynthesis, photon energy is captured by pigment molecules in the photosynthetic light-harvesting complexes, creating electronic excitations. Few hundred such antenna pigments serve each photochemical reaction centre, yet, owing to an efficient EET, almost every single excitation is used to initiate a photochemical reaction. The physical mechanisms of EET have been a focal point of research for decades. Theoretically, if the coupling between the electronic transition dipoles of adjacent pigment molecules is weak, excitations are transferred via the incoherent Förster resonance mechanism (FRET). Conversely, strong coupling between the densely packed chlorophylls in the antenna complexes creates quantum coherence, or delocalised excited states, called molecular excitons, that are quantum superpositions of the individual molecular states. On the other hand, coupling to vibrational motions of the surrounding protein matrix destroys the coherence and localises the excitations. The role of quantum coherence in photosynthesis has been a matter of vigorous debate since 2DES experiments showed evidence for long-lived coherence in various biological light-harvesting complexes. In addition to the ability to create and probe coherences between excited states, 2DES can distinguish homogeneous and inhomogeneous broadening, probe solvent relaxation and spectral diffusion dynamics and, most importantly, reveal correlations between excited states and resolve the pathways and kinetics of EET even in spectrally congested multichromophore systems.

YouTube

Lasers in oncotherapy

▶ 11^{00}–11^{45} **Katalin Hideghéty** • **ELI-ALPS** | **Hungary** • ***Ionising radiation for cancer treatment*** YouTube

▶ 12^{00}–13^{00} **Lunch break**

▶ 13^{00}–13^{45}

Jörg Pawelke • **Helmholtz-Zentrum Dresden-Rossendorf** | **Germany** • ***Radiotherapy with laser-driven particle beams***

Within the lecture I will start with an introduction in two basic particle acceleration mechanisms (LWFA, TNSA) and in some basic laser system approaches to achieve the necessary high light intensity for particle acceleration. Then the status of laser-based irradiation technique will be presented, showing that laser-driven electron and ion beams are already used for systematic radiobiological experiments with cell samples and small animals. Finally, the translation of laser-based technology to future clinical application will be discussed with focus on proton therapy.

YouTube

▶ 14^{00}–14^{45}

Elke Beyreuther • **Helmholtz-Zentrum Dresden-Rossendorf** | **Germany** • ***Radiobiology of high-dose-rate pulsed particle beams***

Within the lecture I will give a short introduction in radiobiological methods and assays that were applied for the investigation of high and ultra-high dose rate effects. In the second part of the lecture I will explain exemplary in vitro and in vivo studies on those effects with special focus on laser-driven sources and on new radiotherapeutic regimes based on high dose rate beam delivery (Flash).

YouTube

▶ 15^{00}–15^{45} **Discussion** (moderated by **Katalin Hideghéty**) YouTube

Social programme

Thursday, 8 th July 2021

Applications in medicine and life sciences

▶ 9^{00}–9^{45}

Adrian Podoleanu • University of Kent | United Kingdom • *Optical coherence tomography (OCT)*

Optical coherence tomography (OCT) has been initially developed as a non-invasive high-resolution optical imaging modality for ophthalmology, followed by rolling the technology to other medical fields. An important advantage of OCT is that of high axial resolution, achievable at comfortable working distances, which is an important requirement for safe scanning of patients. The tremendous increase in acquisition speed of the spectral domain OCT technology in the last decade has allowed the OCT community to achieve fast real-time volume display and has opened the field of no-dye angiography and that of fast interrogation of deformation patterns in elastography. Recent research in Kent has combined spectral domain and time domain OCT principles into a new method, Master/Slave, that delivers fast displays of enface OCT images. The Master/Slave method simplifies the OCT technology, the signal processing as well as gives parallel, direct access to information from multiple depths in the tissue, in real time. Recent developments in ultra high resolution OCT applied to dermatology will also be presented.

YouTube

▶ 10^{00}–10^{45}

Justin E Molloy • Francis Crick Institute | United Kingdom • *Single-molecule experiments using optical tweezers*

The monochromatic and highly collimated nature of laser light means that it can be focussed to a diffraction-limited spot by a high numerical aperture microscope objective lens. The Gaussian intensity profile of the focal spot has a diameter roughly half that of the optical wavelength. In the early 1970s, Arthur Ashkin (who won the Nobel prize in physics in 2018) demonstrated that a tightly-focussed beam of light can produce an optical trap capable of confining small particles to a fixed position, overcoming the forces due to Brownian motion. By moving the spot of light the trapped particle could then by manipulated, hence the term 'optical tweezers' was coined.

In the 1990s, optical tweezers were used to measure the mechanical properties of biological macromolecules, in particular the class of proteins known as molecular motors, that power contraction of muscles and drive intracellular motility. The forces exerted by optical tweezers happen to be of exactly the correct magnitude to allowed calibrated measurements of forces in the range of piconewtons and displacements of nanometres.

This lecture will describe how optical tweezers are built and calibrated and how they have been used to make single-molecule measurements. The use of an allied laser-based method called total internal reflection fluorescence microscopy will also be discussed.

YouTube

▶ 11^{00}–11^{45}

Ronald Sroka • Ludwig-Maximilians-Universität München | Germany • *Light for medical application*

Biophotonics and laser medicine are dynamic and continuously increasing fields. Direct communication with medical doctors is necessary to identify specific requests and unmet medical needs. Knowledge about innovative, new or renewed techniques is necessary to design medical devices for introduction into clinical application. Thus, having the potential to become established after positive clinical trials as well as after medical approval. The long-term endurance in developing light based innovative clinical concepts and devices are described based on the Munich experience. Fluorescence technologies for laboratory medicine to improve noninvasive diagnosis or for online monitoring are described according with new approaches in improving photodynamic therapeutic aspects. Clinical thermal laser applications, the introduction of new laser wavelengths and laser parameters showed potential in the treatment of varicose veins, lithotripsy and surgical interventions. Such directly linked research and development are possible when researchers and medical doctors perform their daily work in immediate vicinity, thus having the possibility to share their ideas in meetings by day.

YouTube

▶ 12^{00}–13^{00} **Lunch break**

Ultrafast laser pulses

▶ 13^{00}–13^{45}

Helder Manuel Paiva Rebelo Cerejo Crespo • Universidade do Porto | Portugal • *Fundamentals of ultrashort laser pulse generation, measurement and control*

Ultrafast femtosecond lasers are a key tool for cutting-edge science and applications. In this talk, we will review the basics of ultrashort pulse generation from mode-locked lasers, methods for laser pulse amplification and temporal compression and techniques for their temporal characterisation and control, with emphasis on the dispersion scan technique.

YouTube

▶ 14^{00}-14^{45}

Rosa Maria Romero Muñiz • Universidade do Porto | Portugal • *Ultrashort laser pulses in medical imaging and therapy*

Ultrashort laser pulses deliver broadband sources for excitation of multiple fluorophores at the same time, thus providing to medical imaging systems an advanced tool for imaging deeper into samples. Furthermore, due to their short pulse duration and smaller average power they also allow to extend the life time of in vivo samples. Ultrashort laser pulses can also be used in surgery for removing damaged tissues in very difficult areas with reduced access, proving to be excellent tools in medical applications.

YouTube

Social programme

Friday, 9th July 2021

3D printing

▶ 9^{00}–9^{45} **Zsolt Geretovszky** • **University of Szeged** | **Hungary** • ***3D printing: the manufacturing technology that revolutionises medical treatments*** — YouTube

The colloquial term 3D printing describes a novel way for constructing three-dimensional objects. Although the scientific background of 3D printing was mainly laid in the 1980s, the technology needed some time to prove its potential and some further years before its mainstream-market adoption started to take off. By now, some variants of the technology are mature enough to offer machines capable to serve the needs of serial production and 3D printing started to receive significant publicity.

Today, the term 3D printing is getting replaced by additive manufacturing, or AM as short, as the latter expresses the very essence of these building strategies unambiguously, namely that an object is constructed from the bottom up by adding or joining the elements of the object (ranging in size from molecules to grains of powder or fine filaments) in a layer-by-layer fashion. Moreover, the word 'additive' also clearly differentiates AM from traditional subtractive manufacturing. The freedom with which AM allows to produce unique, individual parts with an unprecedented ease is the key behind how this disruptive technology revolutionises manufacturing in general. The healthcare sector is always at the forefront of manufacturing in many ways by demanding ultimate performance for its products. It is therefore not a surprise that the medical application of AM technologies got a momentum early and medical applications are amongst the first implementers and key developers of AM technologies.

This talk is meant to be an introductory lecture on additive manufacturing, aiming to set grounds by defining and explaining the core ideas of AM, introducing the underlying processes by which the layer-by-layer growth of a 3D object can be realised. Although the name '3D printing' may sound appealingly simple, AM is not a push-of-a-button technology. Therefore, in the second part of the lecture I will give a general procedure, in which I will list and explain each and every step that may be necessary for producing a 3D printed object, from conceiving the idea until we hold the actual part in our hands. Along the way, I will touch upon the most popular variants of AM and will show what this revolutionary way of production may offer to medical professionals and the healthcare sector.

▶ 10^{00}–10^{45} **Endre Varga** • **University of Szeged** | **Hungary** • ***High-tech traumatology: possibilities of 3D printing in traumatology*** — YouTube

▶ 11^{00}–11^{45} **Discussion** (moderated by **Ferenc Bari**) — YouTube

▶ 12^{00}–13^{00} **Lunch break**

▶ 13^{00}–17^{00} **Closing test** — CooSpace