Bio Photonics

Harnessing light for the Life Sciences

Professor Andersson-Engels is recruited as the Group Head of the newly established Biophotonics@Tyndall Group based at the Tyndall National Institute. The Group has been set up with generous financial support and infrastructure support which provides fantastic opportunities for world-class research within biophotonics. The Group’s major focus will be to form close collaborations with clinicians, research centres and companies to accelerate biophotonics technology and rapidly deliver this new technology into the hands of health-care providers. Using photonics as a driver for the faster development and deployment of more accurate, less invasive diagnostic and treatment methods for cancer and other diseases, the ultimate aim of Biophotonics@Tyndall is to radically improve health outcomes for patients.

Ireland is host to more than 350 medical technology companies, including 13 of the top 15 global med-tech companies, employing 25,000 people and exporting over €8 billion. IPIC is engaging with these companies to explore the integration of photonics into their future products to improve functionality, performance and value.

System scale is a critical parameter for health applications, such as wearable diagnostics and surgical instruments and therefore miniaturisation is an absolute requirement to achieve deployable solutions. The opportunities for IPIC technology to impact the health sector is huge – enabling the transition of diagnostics from highly specialised reference laboratories, to local point-of-care settings, and potentially to wearable devices.

In addition the technology can be integrated onto surgical instruments to guide surgeons during procedures to improve patient outcome. Our core research programme in this area is focused on the development of compact optical sensors that can be integrated with instruments, wearable devices, implants, smart-phones or optical fibres and the development of flexible microleds for optogenetics. Potential applications here include retinal, neuroscience and heart stimulation. Examples of where this technology can be applied to a number of biophotonics platforms include: In body O2 tissue sensing, microfluidics, optical coherence tomography (OCT). Our researchers are also leveraging the emerging science of silicon photonics and hybrid and monolithic integration technologies to dramatically reduce device size.

Scientific challenges being addressed here include: Integration of discrete light sources onto silicon based biosensors & the integration of photonics and electronics onto compact microfluidic devices. This research has already resulted in the integration of optical fibres onto arterial guidewires and the first generation of miniaturised fluorescence sensing modules for blood and hormone analysis.

The Biophotonics@Tyndall Group research programme will include the following projects, which are divided into application-driven and fundamental research/technology-platform driven tasks.

- **Application-driven tasks:** aimed at finding solutions to identified clinical and preclinical challenges. Novel studies and developments will focus on well-known techniques and principles such as diffuse reflectance, fluorescence, Raman and photoacoustics.
- **Fundamental research/Technology-platform tasks:** aimed at developing novel biophotonics optical techniques beyond the state-of-the-art, thus providing new techniques that can
Application driven tasks: Clinical & Preclinical challenges: Several issues will be studied with an application focus, initially with techniques deemed to be the most promising for that particular task, and then, when necessary, complemented with more sophisticated multimodal techniques. The proposed primary targeted medical application projects integrate well with ongoing activities at the various clinics, and aim to translate into clinically evaluated prototypes for patient care. This part of

Optical diagnostics and guidance of medical interventions: Many diagnostic procedures, clinical interventions and preclinical studies would tremendously benefit from improved guidance. Five areas of research are included in this proposal:

- **Gastrointestinal interventions (GI)** where the challenges can be guiding resections during e.g. laparoscopic-surgery and treatment of inflammatory bowel disease.
• Multicentre study for **HPV-positive oral cancer screening** (ENT) together with NUIG.
• **Reconstructive bone surgery** (Bone) where it is essential to keep the periosteum (bone membrane) intact on the lateral side of the bone when making holes for screws.
• **Surgical guidance for resection of malignant lesions in the brain** (Brain) where it is difficult to discriminate malignant and surrounding brain tissue during operation.
• Monitoring of **lung function** and tissue oxygen saturation in **neonatal care** of term and premature babies; and probing for **diseases in the airways** (Lung).

**Technology–platform tasks: Deep tissue imaging/therapy with optical contrast:** Fundamental biomedical optics research will involve two principally different principles for deep tissue imaging/manipulation with optical contrast:

• **Upconverting nanoparticles (UCNPs).**
• **Wavefront engineering based on ultrasound light tagging (USLT) & optical phase-conjugation focusing (OPCF).**

A major challenge is the relative poor light penetration in tissue due to high scattering. This also results in limited spatial resolution. The aim is to develop novel techniques for optical imaging deep in tissue with previously unseen spatial resolution:

• **UCNPs:** Optical imaging based on UCNPs as a contrast agent. The main focus of the project will initially be the development of novel imaging and tomography schemes, as UCNPs, with their unique properties, can provide improved image qualities and depth sensitivity. In particular we plan to explore the background-free signal and non-linear excitation properties to optimally assess tissue information. Secondly we also intend to utilise UCNPs for **deep tissue photo-activation** and **luminescence microscopy on stained histopathological paraffin sections.** The UCNP-mediated activation is of interest as we can potentially reach cells deep into tissue, as the conventionally required blue excitation is transferred to the NIR wavelength region with high penetration in tissue. Today, immunohistochemistry by fluorophore-stained histopathological microscopy requires frozen sections, as the otherwise preferable preparation, formalin fixation and paraffin embedding, gives far too strong background fluorescence. By utilising UCNPs as a staining agent, this background can be totally eliminated, yielding tremendous simplifications in the sample preparation.

• **USLT and OPCF:** Ultrasound light tagging and optical phase-conjugation focusing as novel techniques for **labeling and focusing light deep into highly scattering tissue.** One way to accomplish both these effects is using focused ultrasound as a “guidestar” together with **light waveguide engineering.** Light scattered in a volume exposed to ultrasound (US) will experience a wavelength shift due to the ultrasound wave. By filtering out only the wavelength-shifted light it is possible to map optical characteristics of tissue with a resolution of the focused ultrasound beam. It has recently been suggested that light can also be focused to locations deep into highly scattering media using USLT. The development of such technique would open up entirely new avenues for biomedical diagnostics and therapy. This would be a non-invasive label-free technique, thus non-toxic and with potentially great clinical impact.

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