1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan, all in English)

Project title:

Acousto-Optically Modulated Vector Beams in High-Resolution Biomedical Imaging

1.1. Project goals

- To combine acousto-optics and singular optics technologies in biomedical imaging
- To develop methods for tuning the parameters of vector beams using acousto-optics
- To study the advantages of singular optics in microscopy
- To develop microscopy system employing tunable vector beam for high-resolution optical imaging

1.2. Outline

Recent advances in **photonics** has brought about a revolution in optical microscopy that now enables high-resolution visualization of biological objects at different scales of organization. **The advances in optical engineering allows for the development of novel tools that can be used in the innovative optical microscopy** [1]. Optical imaging has found **numerous applications especially in biomedicine**, where it offers potential to differentiate tissues without exogenous contrast. With these features, optical imaging technologies are becoming powerful clinical tools for non-invasive and objective diagnosis, guided treatment and monitoring therapies [1].

Optical vector beams represent non-standard optical fields, in which polarization depends also on the transverse coordinates across the beam. Light vortices have a variety of applications in optical manipulation, optical communications and microscopy [2-5]. **Acousto-optics** is a branch of science studying with the interaction of light with ultrasound. Acousto-optics represents the field with numerous applications. in particular, acousto-optic devices are heavily used in high-speed modulation of optical fields [6-8].

In spite of technology advances, **modern optical imaging methods still exhibit several challenges** which are mainly related to the ability of the system to distinguish details of the imaged object. This project aims at **addressing these issues by using acousto-optofluidic devices and singular optics to shape the light. We would like to develop optical microscopy system utilizing specific tunable vortex beam for efficient three-dimensional imaging.**

In this project, the student will assess the performance of the high-resolution optical microscopy with switchable vector beams, and will apply the microscopic system in the imaging of biological samples. The project combines singular optics, acousto-optics and biophotonics to study new class of optical systems and its usefulness in imaging technologies. The results of the project will trigger the development of novel approaches to the field of high-speed imaging. Improvements in the performance of the optical instrumentation will represent a key step in developing tools for more efficient visualization of specimens with optical methods.

1.3. Work plan

- Theoretical study of the performance of an acousto-optic lens (modulator) illuminated with

light field of different phase and amplitude distribution. Experimental verification of the calculations

- Assessment of the methods for generation of optical vortices (taking into account applicability in imaging system)
- Comparison of the static and dynamic optical votrex
- Design and optimization of the optical system with acousto-optically tunable vortex
- Development of the system and comparison its performance with regular optical microscopy

1.4. Literature

[1] E.A.Swanson, J.G. Fujimoto, The ecosystem that powered the translation of OCT from fundamental research to clinical and commercial impact [Invited], *Biomed. Opt. Express* **8** (2017), 1638.
[2] M.Ritsch-Marte, Orbital angular momentum light in microscopy, *Phil. Trans. R. Soc. A* **375** (2017), 20150437.
[3] E.Edrei, G.Scarcelli, Optical Focusing beyond the Diffraction Limit via Vortex-Assisted Transient Microlenses, *ACS Photonics* **7** (2020), 914.
[4] Y.Shen, X.Wang, Z.Xie, C.Min, X.Fu, Q.Liu, M.Gong, X.Yuan, Optical vortices 30 years on: OAM manipulation from topological charge to multiple singularities, *Light Sci. Appl*. **8** (2019), 90.
[5] M.Szatkowski, A.Popiołek-Masajada, J.Masajada, Optical vortex in microscopy imaging, *Proc. SPIE* **9194** (2014), 91941D.
[6] I.Grulkowski, S.Manzanera, L.Cwikliński, F.Sobczuk, K.Karnowski, P.Artal, Swept source OCT and tunable lens technology for comprehensive imaging and biometry of the whole eye, *Optica* **5** (2018), 52.
[7] X.Yang, B.Jiang, X.Song, J.Wei, Q.Luo, Fast axial-scanning photoacoustic microscopy using tunable acoustic gradient lens, *Opt. Express* **25** (2017), 7349.
[8] K.Szulzycki, V.Savaryn, I.Grulkowski, Generation of dynamic Bessel beams and dynamic bottle beams using acousto-optic effect, *Opt. Express* **24** (2016), 23977.

1.5. Required initial knowledge and skills of the PhD candidate

- Energy and motivation to conduct research and to turn challenges to opportunities,
- Good communications skills,
- Knowledge on theoretical or experimental optics, in particular on development of simple optical systems (advantageous),
- Not required but welcome: basic skills in computer programming.

1.6. Expected development of the PhD candidate's knowledge and skills

Core skills:

- Integrated training in biomedical photonics, data acquisition and data processing,
- Optical engineering methods and tools for design and optimization of advanced optical

systems,

- Experience in development of advanced optical imaging modalities (microscopy, tomography etc.),
- Knowledge on theoretical and experimental acousto-optics,
- Knowledge on singular optics (e.g. optical vortices).

Transferrable (soft) skills:

- Analytical thinking,
- Good laboratory practices,
- Project management,
- Science communication for different audiences (incl. oral and poster presentations),
- Scientific writing,
- Team work & international cooperation.