3 years PhD position - starting fall 2018 (funding secured):

Minimally-invasive photoacoustic microendoscopy

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General context of the work: Photoacoustic imaging is a multi-wave **biomedical and optical imaging** modality based on the photoacoustic effect, i.e. the emission of ultrasonic waves due to light absorption. In the last ten years, recognition of advantages of photoacoustics over other biomedical imaging techniques resulted in a tremendous increase in the amount of biomedical research devoted to photoacoustic imaging. The photoacoustic effect is specific of optical absorption, and it is therefore possible to develop photoacoustic microscopy methods that image selectively and with high resolution the distribution of optical absorption, as opposed to other microscopy techniques based on scattering or fluorescence for instance. However, (photoacoustic) microscopy in tissues is limited by scattering to surface or shallow-depth imaging. A possible approach to perform **optical microscopy deep in tissue** is to use endoscopic methods, but at the cost of invasiveness. In the context of the ERC-funded COHERENCE project, **our group develops new methods for photoacoustic imaging [1-5],** including minimally invasive photoacoustic microendoscopy. At the core of the endoscopy project is the demonstration in recent years that multimode optical waveguides may be used to perform high-resolution optical imaging, with a footprint much smaller than conventional approaches based on fiber bundles or scanning-based devices, for comparable imaging performances. In multimode waveguides, there exists a complex but deterministic and linear relationship between the input and output wave patterns, which requires to first characterize the waveguides before they can be used for imaging. But once the waveguides have been characterized, several approaches may be implemented to perform imaging, either based on raster-scanning a focused spot or on wide-field illumination. In our group, **we develop innovative approaches to perform photoacoustic microendoscopy in biological tissue at the minimal possible invasiveness**.

PhD project: The general objective of the PhD project will be to design a prototype of minimally invasive photoacoustic microendoscopy. In terms of instrumentation, one challenge will be to develop novel methods to build a fast-imaging device: the approaches implemented to date are too slow to be used for biomedical purposes, as they not only require very long calibration steps but also very long acquisition times. Another general challenge for optical microendoscopy with multimode waveguides is the sensitivity of multimode propagation to the fiber conformation, which to date has limited the approach to rigid devices. One objective of the PhD project will be to develop and implement innovative methods to perform microendoscopy with a flexible device. The PhD project will involve both experimental and methodological developments. The experimental work will involve optical wavefront shaping with DMDs (Digital Micromirror Devices), propagation in various types of multimode optical waveguides, laser sources and ultrasound detection. The methodology involves transmission matrix approaches, phase retrieval algorithms, image reconstruction methods. The new developed approaches will be designed and tested with both experiments and simulations. Depending on the applicant's profile and motivation, the project may involve aspects on innovation and technology transfer [5].

Skills: The PhD work will requires an excellent background in **physics and/or engineering**. In particular, a **strong knowledge and motivation in wave physics is essential**, preferentially in optics or electromagnetism. Notions in image formation are also welcome (resolution, point spread function …). **Matlab** will be used for simulation, data analysis and instrumentation. A **very good spoken and written English** is required. Applicants with a motivation for innovation and technology transfer are welcome.

Funding: The PhD salary is already available via the ERC grant COHERENCE. The monthly net salary is 1460€, over a total period of 36 months.

Supervision: The PhD thesis will be supervised by Pr. Emmanuel Bossy, and the PhD work will involve a close interaction with Dr. Antonio Miguel Caravaca Aguirre (post-doctoral researcher).

Location: The PhD work will take place at the Laboratoire Interdisciplinaire de Physique, which is located on the campus of the University Grenoble Alpes. Grenoble is an extremely dynamic and academic global city, with low rents.

Recent references on photoacoustic imaging in the group:

[1] Chaigne, T., Arnal, B., Vilov, S., Bossy, E., & Katz, O. (2017). Super-resolution photoacoustic imaging via flow-induced absorption fluctuations. *Optica*, *4*(11), link to article. See press release in Physics Today: "Photoacoustic imaging beats the diffraction limit".

[2] Vilov, S., Arnal, B., & Bossy, E. (2017). Overcoming the acoustic diffraction limit in photoacoustic imaging by the localization of flowing absorbers. *Optics letters*, *42*(21), link to article.

[3] Chaigne, T., Gateau, J., Allain, M., Katz, O., Gigan, S., Sentenac, A., & Bossy, E. (2016). Super-resolution photoacoustic fluctuation imaging with multiple speckle illumination. *Optica*, *3*(1), link to article.

[4] Bossy, E., & Gigan, S. (2016). Photoacoustics with coherent light. *Photoacoustics*, *4*(1), link to article.

Patents:

[5] Bossy E., Huignard JP., Simandoux O., Papadopoulos I., Farahi S., Stasio N., Moser C., Psaltis D. "Minimally invasive optical resolution photoacoustic endoscopy with a single waveguide for light and sound", US20160143542A1, may 2016.