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PhD on ultra-sensitive sensors based on ultra-coherent lasers

Source operating at Schawlow-Townes quantum limits

Starting date: October 2022

Supervisor: Pascal Besnard, Luiz Poffo

Financial support: acquired, ministry scholarship

Team: Photonic Systems at Foton Institute, France

Key-words: Brillouin lasers, frequency noise, coherency, tunable lasers, mode-locked lasers, sensors

Context

In many photonic systems, the emitter is a laser source, whose noise becomes the main system limitation, even if it can be considered low. Many laboratories in the world study coherent sources to address different areas of applications: fundamental research (quantum, gravitational waves...), defense, telecommunications, environment...

Subject

A research theme of the Foton Institute concerns coherent sources. We acquire an expertise in the realization of coherent sources. The latest works concern the study of Brillouin lasers at the best state of the art. Thus, we have realized very coherent C-band-tunable sources. We do not know how to characterize these sources in terms of coherence because they are below the noise floor of our characterization bench (sub-mHz intrinsic width and sub-kHz integrated noise). This work has revealed the physics of synchronization by an ultra-coherent laser. This type of source allows significant advances from a scientific and industrial point of view (fundamental study of synchronization processes, instrumentation, realization of sensors,...)

Research Program

The subject of this thesis is to explore the Schalow-Townes quantum limits of a laser. It is also to use these sources for the detection of extremely low continuous flux of photons (in the attoWatt-femtoWatt range at room temperature) or the detection of very few photons (less than a hundred). The Ph.D. student will compare the experimental results to simulations using an original theoretical model. Finally, he/she will develop techniques for measuring very fine signals (sub mHz: nano-Hertz, µHz).

On this last point, the use of very coherent mode-locked sources will be implemented while waiting for the use of a metrological signal (French project REFIMEV; https://www.refimeve.fr/). A significant budget is dedicated to the project (400 k€) in terms of new equipment acquired during the thesis.

The potential for an extension to other domains (visible, MIR) will be explored.

M. Sahni, S. Trebaol, L. Bramerie, M. Joindot, S. Ó Dúill, S. Murdoch, L. Barry, and P. Besnard, "Frequency noise reduction performance of a feed-forward heterodyne technique: application to an actively mode-locked laser diode," Opt. Lett. 42, 4000-4003 (2017).

A. Sebastian, I. V. Balakireva, S. Fresnel, S. Trebaol, and P. Besnard, "Relative intensity noise in a multi-Stokes Brillouin laser," Opt. Express 26, 33700-33711 (2018).

A. Sebastian, S. Trebaol, P. Besnard, "Intracavity Brillouin gain characterization based on cavity ringdown spectroscopy," OSA Continuum, OSA Publishing, 2019, 2 (12), pp.3539-3545.

A. Karuvath, A. Sebastian, P. Besnard, "C-Band tunable Brillouin fiber-laser with sub-Hz intrinsic linewidth," oral presentation Paper 12142-56, Photonics Europe, Strasbourg 2022.

Qualifications

Candidates should have good knowledge in the areas of optics and laser physics. A previous experience in laser physics would be greatly appreciated. The ideal profile would combine interest for experimental work and for modelling and simulation works. Good interpersonal and communication skills in French or English are required. The applicant must hold an internationally recognized Master degree.

Partenariat

A French national project initiated this project through a collaboration with different partners (academics and industry). One part the Ph.D. work is to prepare the experimental and theoretical tools to welcome an optical signal of reference, which will enable us to go to accurate measurements. This optical reference signal from an optical clock is distributed through the French project equipex T-REFIMEVE. The objective of T-REFIMEVE is to provide the scientific community and industrials with a complete set of timing signals at the best international level that metrology laboratories can provide, taking advantage of the exceptional accuracy of atomic clocks and the guided propagation in optical fibers.

About the Institut Foton (CNRS, UMR6082)

The Institut FOTON is a research unit of the French National Centre for Scientific Research (CNRS) associated to University of Rennes 1 and the National Institute for Applied Sciences (INSA) of Rennes. FOTON is composed of three research teams: the "Optoelectronics, Heteroepitaxy and Materials" team, the "laser Dynamics, microwave photonics, Polarimetry, terahertz, imaging" team located in Rennes, and the "Photonic Systems" team located in Lannion. The two cities are located approximatively 170 km apart, in the province of Brittany, Western France. Photonic Systems team (~50 people) is involved in research on laser physics, and in particular on the experimental demonstration of new functionalities that could potentially contribute to overcoming the challenges related to sensors sensitivity, telecom capacity and guided optics (fibers and integrated photonics) in particular for sensing and nonlinear applications. The group has an established reputation in the area of laser physics and mid-IR integrated photonics. All the simulation and experimental tools required for the project completion are available within the Photonic Systems Team in Lannion.

The successful candidate will carry out research in Lannion (France).

More information about Institut FOTON can be found at: http://foton.cnrs.fr.

Contact

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Application procedure

Your application should include:

- Cover Letter
- Detailed CV
- Name and contact details of two potential referees with recommendation letters
- Grade transcripts
- List of publications, if applicable