Post-doc position available:

Low-noise optical and optoelectronic oscillators. Application to metrology and microwave photonics.

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Description:

High stability and low-noise continuous and mode-locked laser sources are becoming key elements of more and more advanced experiments and architectures that address a large area of applications, from fundamental physics to metrology. These laser sources indeed offer unprecedented properties in terms of spectral purity, pulse repetition rate stability and spectrum spanning. A particularly important domain of application is the frequency and time reference signals generation. Low noise and high stability frequency and time reference sources are fundamental elements of advanced sensing, positioning, navigation and communication systems, since they directly impact their performances (sensitivity, precision, bit rate…).

Over the past recent years, optics has brought new approaches to address challenging problems that are faced by microwave electronics in this domain. Depending on the required phase noise performances, long term stability, and environmental constraints, different opto-electronics architectures have been proposed and demonstrated, outperforming traditional electronics-based solutions. Among these architectures, optoelectronic oscillators and coupled optoelectronic oscillators have proven to provide, in a simple setup, phase noise performances exceeding the ones of multiplied quartz oscillators that are implemented in most systems. It has been recently shown that it is even possible to outperform the performances of cryogenic sapphire oscillators, the best known microwave oscillators, with the technique of "optical frequency division", based on the combination of a continuous laser and an optical frequency comb delivered by a mode-locked laser. Moreover, Frequency combs have generalized access to frequency references for new metrology laboratories. Finally, single and dual frequency vertical external cavity semiconductor lasers (VECSELs) are promising sources for microwave signal generation and metrology applications due to their unique low noise properties.

For all these architectures and laser sources, it is crucial to get a better understanding of the noise sources and coupling mechanisms that directly impact the performances. Our team in Laboratoire Aimé Cotton is involved in several collaborative projects with different partners, both industrial (Thales Research & Technology, Thales Electron Devices, Thales Alenia Space, OSAT) and academic (SYRTE, IOGS, LAAS, LPN, LKB), for its expertise in the domains of laser physics, quantum optics, and microwave photonics. These projects aim at building low-noise lasers for i) atomic clocks based on coherent population trapping resonances in cesium vapour; ii) opto-electronic oscillators ; iii) coupled opto-electronic oscillators. In this framework, the tasks devoted to our team are the following:

- Analyze theoretically and experimentally the intensity and phase noises of the two modes of a dual-frequency VECSEL, and their implication on the ukltimate performance of a CPT cesium clock. Special attention will be devoted to the understanding of the correlations between these different noises;
- Analyze theoretically and experimentally the noise transfer of a low-noise laser to the RF signal generated by an optoelectronic oscillator based on this laser.
- Analyze theoretically and experimentally the noise of actively mode-locked lasers (based on semiconductor optical amplifiers) used in a coupled optoelectronic oscillator (laser

actively mode-locked by the optoelectronic oscillator signal it is involved in). This will take into account the different noise sources (spontaneous emission, pump noise, etc…) and the different noise conversion mechanisms in the optical fibers (dispersion induced amplitude to phase noise transfer), the semiconductor optical amplifiers (dynamic saturation), and the detector.

The candidate will take part in both experimental and theoretical/numerical developments. He/she will be also involved in the collaborative aspects of this work, in interaction with the partners mentioned above. He/she will also have the opportunity to take part in some of the other activities of the group, such as the development of phase sensitive amplifiers for microwave photonics applications.

<u>Some references:</u>

- G. Baili, L. Morvan, M. Alouini, D. Dolfi, F. Bretenaker, I. Sagnes, and A. Garnache, "Experimental demonstration of a tunable dual-frequency semiconductor laser free of relaxation-oscillations," *Optics Letters* **34**, 3421-3423 (2009).
- V. Pal, P. Trofimoff, B.-X. Miranda, G. Baili, M. Alouini, L. Morvan, D. Dolfi, F. Goldfarb, I. Sagnes, R. Ghosh, and F. Bretenaker, "Measurement of the coupling constant in a two-frequency VECSEL," *Optics Express* **18**, 5008-5014 (2010).
- A. El Amili, B.-X. Miranda, F. Goldfarb, G. Baili, G. Beaudoin, I. Sagnes, F. Bretenaker, and M. Alouini, "Observation of slow light in the noise spectrum of a vertical external cavity surface emitting laser," *Physical Review Letters* **105**, 223902 (2010).
- A. El Amili, V. Pal, F. Goldfarb, R. Ghosh, M. Alouini, I. Sagnes, and F. Bretenaker, "Observation of noise phase locking in a single-frequency VECSEL," *Optics Express* **19**, 17250-17259 (2011).
- S. De, G. Loas, A. El Amili, M. Alouini, and F. Bretenaker "Theoretical and experimental analysis of intensity noise correlations in an optically pumped dual-frequency Nd:YAG laser," *Journal of the Optical Society of America B* **30**, 2830–2839 (2013).
- S. De, A. El Amili, I. Fsaifes, G. Pillet, G. Baili, F. Goldfarb, M. Alouini, I. Sagnes, and F. Bretenaker, "Phase noise of the radio frequency (RF) beatnote generated by a dual-frequency VECSEL," *Journal of Lightwave* Technology **32**, 1307-1316 (2014).
- G. Baili, L. Morvan, G. Pillet, S. Bouchoule, Z. Zhao, J.-L. Oudar, L. Ménager, S. Formont, F. Van Dijck, M. Faugeron, M. Alouini, F. Bretenaker, and D. Dolfi, "Ultra-low noise and high power VECSEL for high dynamic range and broadband RF/optical links," *Journal of Lightwave Technology* **32**, 3489-3494 (2014).
- S. De, V. Potapchuk, and F. Bretenaker, "Influence of spin dependent carrier dynamics on the properties of a dual-frequency vertical-external-cavity surface-emitting laser (VECSEL)," *Physical Review A* **90**, 013841 (2014).
- S. De, G. Baili, M. Alouini, J.-C. Harmand, S. Bouchoule, and F. Bretenaker, "Class-A dual-frequency VECSEL at telecom wavelength," *Optics Letters* **39**, 5586-5589 (2014).
- S. De, G. Baili, S. Bouchoule, M. Alouini, and F. Bretenaker, "Intensity and phase noise correlations in a dual-frequency VECSEL operating at telecom wavelength," *Physical Review A* **91**, 053828 (2015).

<u>Skills:</u>
- Laser physics
- Microwave photonics

<u>Duration:</u> 1 year with 1 year possible extension