Microwave photonics

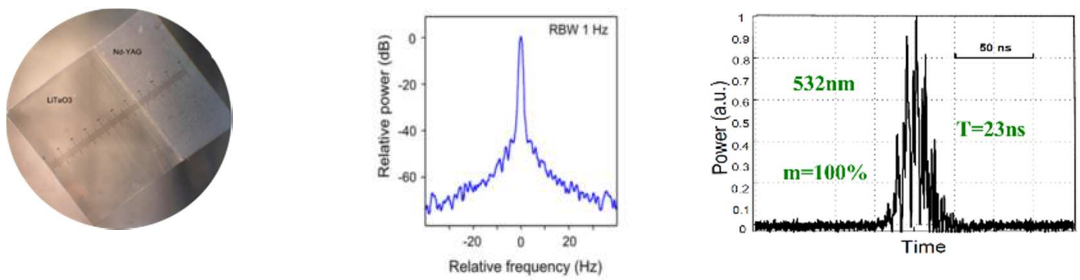
This scientific activity aims at generating and stabilizing microwave signals on optical carriers. High-stability frequency references generation in the microwave range can indeed lead to applications such as optical distribution of clocks or analogic signals for all-optical radar processing. In parallel, the theoretic and experimental study of microwave photonics links - as the one inserted in most recent radar architectures - is another field of research. Lastly, this research field aims at designing new architectures for highly tunable opto-electronic oscillators.

The studies conducted in this domain are closely related to other research fields investigated by the team, such as **Laser dynamics**, **TeraHertz and metrology**, but also to some of our developments in **Advanced imaging**.

Programmable optical generation of radiofrequency & microwave signals

The dual-frequency laser sources that we realize behave as microwave photonics oscillators. Indeed, the laser cavities developed in the FOTON-DOP team produce microwave photonics signals (beatnotes) on an optical carrier. The frequency of the microwave beatnote can be controlled and tuned through an electrical voltage and/or temperature control. These lasers can then be used as voltage controlled oscillators (VCO) in phase lock loops (PLL). We pursue the development of stabilization techniques which can address, at will: a) a small beatnote spectral width, b) the very high spectral purity of the beatnote phase noise, or c) frequency agility of the beatnote.

In the first cases, we show that implementing analogical phase lock loops enables the spectral purity of a radiofrequency synthesizer to be directly replicated on the beatnote frequency, hence leading to spectral widths below one mHz. To address spectral agility, digital solutions must be preferred. In particular, using monolithic dual-frequency lasers along with digital phase lock loops allows tunable frequency synthesis with a phase noise as low as the theoretical limit [Rol11]. We currently use these stabilization techniques on solid state lasers for clock distribution on optical fiber links, and for telemetry applications (Lidar-Radar) [Val13]. In addition, we demonstrated that combining Q-switched lasers and frequency-shifting external cavitiesmakes it possible to design RF-modulated green laser that could find applications in underwater detection and ranging (lidar) [Zha16].



(a) (b) (c)

Fig. 1: a) Picture of a monolithic laser microchip with Nd:YAG gain medium and $LiTaO_3$ electro-optic crystal that behaves as a 40 GHz microwave photonics oscillator controlled by voltage ; b) Stabilized beatnote spectrum ; c) output pulse of a Q-switched laser with frequency-shifting external cavity.

Selected publications*:*

[Val13] M. Vallet, J. Barreaux, M. Romanelli, G. Pillet, J. Thévenin, L. Wang, M. Brunel, "Lidar-radar velocimetry using a pulse-to-pulse coherent rf-modulated Q-switched laser," Applied Optics, 52 (22), 5402-10 (2013).

[Zha16] H. Zhang, M. Brunel, M. Romanelli, M. Vallet, "Green pulsed lidar-radar emitter based on a multipass frequency-shifting external cavity," 55, 2467 (2016).

[Rol11] A. Rolland, M. Brunel, G. Loas, L. Frein M. Vallet, M. Alouini, "Beat note stabilization of a 10-60 GHz dual-polarization microlaser through optical down conversion," Opt. Exp. 19, 4399-4404 (2011).

Microwave photonics links modeling

Performances of microwave photonics links for analogic signals transmission

Hybrid oscillators with opto-electronic feedback semi-conductors bi-lasers

Optical control of antennas

Optical amplification

PhD theses (past / ongoing):

Antoine Rolland, « Oscillateurs ultrastables millimétrique et teraHertz par boucle à verrouillage de phase optoélectronique », 2013

Gwennaël Danion, « Oscillateur micro-onde à teraHertz ultra-stable », 2015

Lucien Pouget, « Contribution à l'augmentation des performances de liaisons optiques-hyperfréquences : non-linéarités et bruit »

Gael Kervella, « Circuits intégrés photoniques in InP pour la génération de signaux hyperfréquences », 2015

Thong Tien Pham, *« Étude et conception d'antennes réseaux transmetteurs millimétriques à reconfiguration par voie optique »*

Aurélien Thorette, *«Structures de polarisation dans les lasers et réinjection : application à la génération de faisceaux opto-hyper »*

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Thales Systèmes Aéroportés
Thales Air Defense
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Selex, (Italie)
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