TeraHertz and metrology

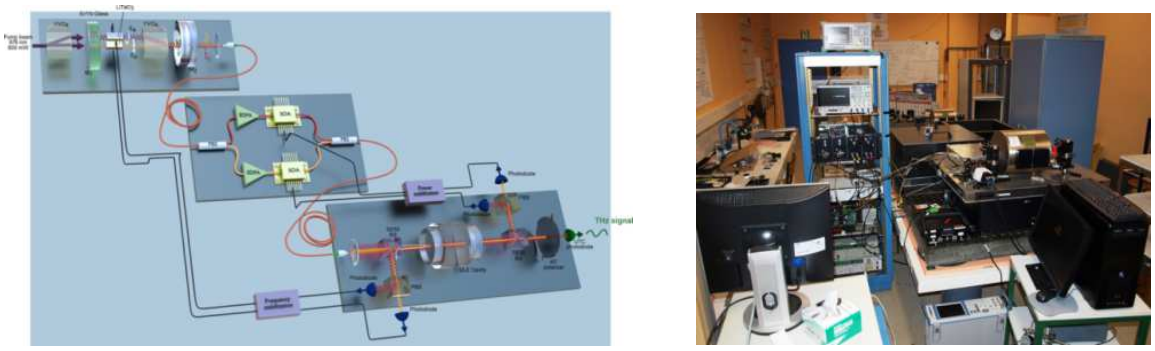
The objective of this research activity is to develop optical means to generate frequency references with high spectral purity in the teraHertz range, with record frequency stability. The applications of such references are high-resolution teraHertz spectroscopy, teraHertz metrology, and heterodyn detection of THz signals at room temperature.

The scientific activities in this domain are closely related to the research carried out in **Laser dynamics**, and correspond to an extrapolation of our work in **Microwave photonics** to the teraHertz range.

Opto-electronic phase lock loop

Very low phase noise microwave/THz signal generation on optical carrier at 1.5 µm

In parallel, we are currently exploring a second approach for THz beatnote stabilization by all-optical means to generate frequency references with metrologic quality in the microwave/THz range. This approach aims at obtaining record performances in terms of phase noise, i.e., much better than the ones obtained by electronical means. In the current setup, the two lines of a dual-frequency, dual-polarization laser at 1.5 µm are stabilized on the same Fabry-Perot cavity of high dimensional stability (finesse of 100 000). For the stabilized laser to remain resonant with the cavity, we have developed a dual-frequency laser whose frequency noise is better than the one of a commercially available single-wavelength laser (for both polarization modes) on a timescale of less than 10 µs [Dan14a]. This laser is followed by an hybrid optical amplifier developed on purpose in the laboratory. It enables amplification of the laser, while reducing its intensity noise, and can be used to stabilize the power on a wide bandwidth [Dan14b]. We also develop the photodetectors adapted to the performances envisaged in this project. To characterize the phase noise obtained once the system will be available, we are currently developing a second identical system, since the expected performances are better than any existing source available to date in the millimeter and sub-millimeter range [Dan13]. In the microwave range, we have demonstrated a phase noise below the resolution of a phase noise measurement bench for frequency detuning from the carrier above 10 kHz [Dan15].



(a) (b)

Fig. 4 : (a) Schematics of the setup allowing locking of the two modes of a dual-frequency laser at 1.55 µm on an optical cavity with high dimensional stability. (b) General view of the experimental setup for microwave/THz signal generation very low phase noise.

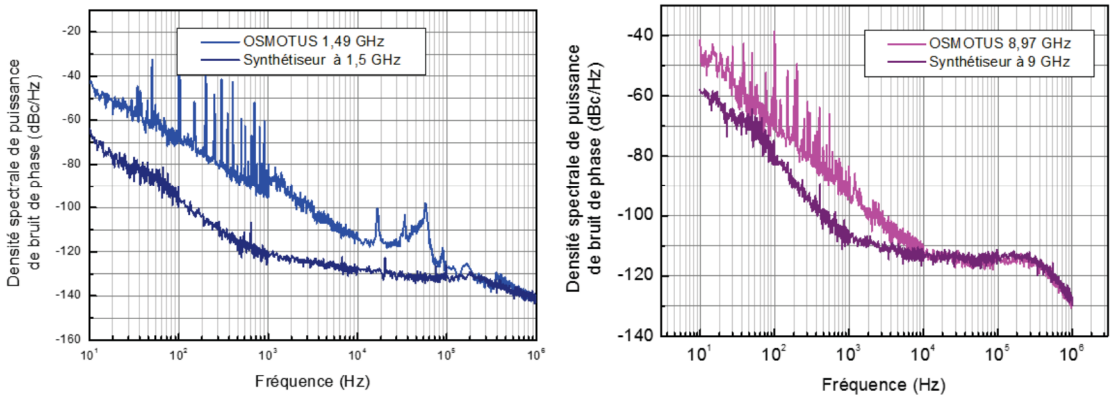


Fig. 5 : Phase noise measurements of the OSMOTUS demonstrator at 1.5 GHz (left) and 9 GHz (right) with a PN 9000 phase noise measurement bench, compared to a commercial RF synthesizer.

Selected publications:

[Dan13] G. Danion; et al., "High spectral purity microwave and terahertz oscillator," Proceedings of 6th Joint IEEE International Frequency Control Symposium/European Frequency and Time Forum, IFCS-EFTF2-A2-5, 40-42, Prague, Czech Republic (2013).

[Dan14a] G. Danion, C. Hamel, L. Frein, F. Bondu, G. Loas, and M. Alouini, "Dual frequency laser with two continuously and widely tunable frequencies for optical referencing of GHz to THz beatnotes," Opt. Express 22, 17673-17678 (2014).

[Dan14b] G. Danion, F. Bondu, G. Loas, and M. Alouini, "GHz bandwidth noise eater hybrid optical amplifier: design guidelines," Optics Letters, 39, pp.4239-4242 (2014).

[Dan15] Gwennaël Danion, Goulc'hen Loas, Ludovic Frein, *et al.* "Synthèse optique d'ondes hyperfréquences et millimétriques à très bas bruit de phase: résultats préliminaires", COLOQ, Optique Bretagne 2015, Rennes, France. 2015.

Design of a compact optical source of millimeter-wave radiation

Continuous THz source by photomixing at 800nm on Titane-Sapphire dual-frequency cavity

Time-domain teraHertz spectroscopy

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

Joachim Boerner, « Theoretical and experimental study of ultrastable solid-state laser delivering millimeter wave and teraHertz signals »

Ayman Hallal, *« Laser impulsionnel à faible gigue »*

Collaboration:

Institut d'Electronique, de Microélectronique et Nanotechnologie – IEMN (Lille)

Laboratoire de Physique des Lasers, Atomes et Molécules – Phlam (Lille)

Thales Research and Technology (Palaiseau)

Observatoire de Nice-Côte d'Azur

Institut de Sciences Chimiques de Rennes

Resolution spectra systems

Menlo Systems

Contacts:


M. Alouini


F. Bondu


G. Loas


M. Romanelli


M.Vallet

FOTON-DOP team

Head of the team : François BONDU
Tel : +33 223 235 156
francois.bondu@univ-rennes1.fr

Website: http://foton.cnrs.fr/v2016/spip.php?rubrique111

Institut FOTON - Équipe DOP
Université de Rennes 1 – CNRS UMR 6082
Campus de Beaulieu – Bat 11B
263 avenue du Général Leclerc
F-35042 RENNES CEDEX
FRANCE