

Optical Frequency shifting loops for microwave photonics

Conventional electronic generation and signal processing techniques are currently constrained by the speed of analog-to-digital and digital-to-analog converters, which in practice limit the number of samples that can be generated or processed per second. On the contrary, the field of optics offers bandwidths up to THz, which makes it possible to envisage high-performance analog approaches for generating and processing signals. Thus, the field of microwave photonics has grown considerably in recent years, and has given rise to remarkable advances, such as the generation of arbitrary signals, or the realization of different functionalities (Fourier transform in time real, filtering, derivation, integration, Hilbert transform ...)

Since 2014, a close collaboration between researchers from LIPhy (Grenoble) and INRS in Montreal (Hugues Guillet de Chatellus, and José Azaña) has shown the significant potential of optical frequency shifting loops (or FSLs) for microwave photonics. This very simple system (Fig. 1) is composed of an optical fiber loop comprising a frequency shifter (AOFS), an optical amplifier (EDFA), and an adjustable optical filter (TBPF). A coupler makes it possible to inject the loop, and to extract a fraction of the light field circulating therein. This system thus realizes the coherent sum of replicas of the input signal, shifted both temporally and in frequency. This platform has allowed us to demonstrate a number of features, such as the generation of arbitrary chirped RF signals [1], the Fourier transform [2], or the fractional Fourier transform in real time [3]. Note that these optical techniques are intrinsically faster than any electronic technique, because these operations are performed analogically, and do not require acquisition or processing step.

As part of this co-supervisory thesis, we propose to extend the applications of these FSL systems to new analog signal processing functions for the manipulation of information in the time and frequency domain (spectrogram ...), as well as to explore the potential of FSL systems for the implementation of fast digital signal processing functions, e.g. logic gates. Most of this work will take place at LIPhy (Interdisciplinary Laboratory of Physics, Grenoble), based on an existing platform and components. In parallel, in a more forward-looking way, we hope to eventually develop an integrated version of the FSL system on silicon photonics technologies. This study on the integration of FSL systems will be conducted at INRS, which has micro-fabrication and characterization capabilities of integrated photonic systems, as well as a large network of collaborations in integrated microwave photonics. In addition, a number of experiments on ultra-fast optical systems for microwave photonics can be carried out at the INRS.

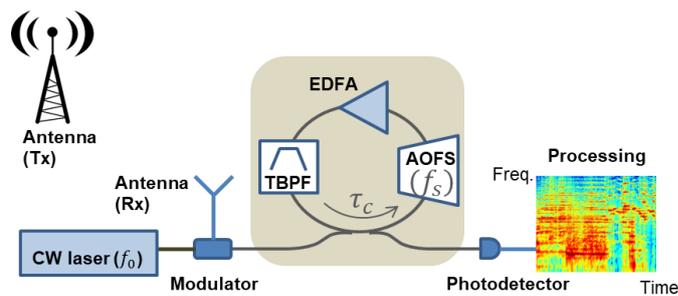


Fig. 1. Experimental device of a FSL loop in spectrogram configuration. The radio signal modulates a CW laser. The modulated laser is injected into a frequency shift loop. Under certain conditions, the loop output intensity periodically reproduces the spectrum of the input signal [2]. By combining the output traces, the spectrogram of the radio signal is reconstructed.

For this thesis with strong experimental emphasis, we are looking for a candidate of a very good level, engineer or holder of a Master's degree, with a solid background in optics. Good knowledge in electronics and signal processing is also desired. The candidate will have to be mobile, to work and adapt in two environments of different cultures. This thesis will enable him/her to acquire experimental know-how on fiber optic systems, signal acquisition and processing, and emerging techniques of integrated photonics. This co-supervisory thesis will take place mainly at LIPhy (80% of the time) and INRS in Montreal (20%). The doctoral student will be registered at the INRS (University of Quebec) and the UGA, and registration fees will be paid to the INRS. The thesis will take place over 4 years, and the diploma will be delivered jointly by the UGA and the INRS. The doctoral student will have to follow teaching modules delivered by the INRS, and will be affiliated to the Doctoral School of Physics of Grenoble.

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- [2] H. Guillet de Chatellus, L. Romero Cortés and J. Azaña, *Optical real-time Fourier transformation with kHz resolutions*, Optica, 3, 1 (2016).
- [3] C. Schnébelin, and H. Guillet de Chatellus, *Agile photonic fractional Fourier transformation of optical and RF signals*, Optica 4, 907 (2017).