INTERNSHIP/ PHD PROPOSAL

Laboratory name: Institut Langevin
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Thesis possibility after internship: YES Funding: YES (ANR grant)

Analog time reversal mirror for radiofrequency signals

Time reversal is a technique based on the invariance of the wave propagation equation in an inhomogeneous medium. It ensures spatial and temporal refocusing of a wave in such a medium, after having recorded the transmission channel signature (ie the response to a short pulse). When the propagation medium is non-stationary, the transmission channel characteristics keep changing. The time-reversed signal must be sent before the medium has changed too much, otherwise the refocusing will not be effective. It is therefore crucial to minimize the latency time between the measurement of the impulse response and the emission of the time-reversed impulse response. In the first demonstrations of time-reversal with RF waves, analog-to-digital converters (ADC) were used, limiting the processing bandwidth. In the aim of reaching the GHz regime, the latency time becomes problematic because of the limited sampling rate of ADCs. We propose to design a fully analog solution to avoid this conversion step.

At Institut Langevin we design original analog architectures for the processing of optically-carried radiofrequency signals. These architectures rely on coherent light-matter interaction in rare-earth ion-doped crystals cooled down to a few kelvin. In these crystals, one can make the atomic medium emit a light pulse with a controlled temporal shape by using the photon echo phenomenon. We will use this photon echo process to generate the time-reversed waveform. We recently proposed a promising time-reversal architecture [1] whose processing bandwidth already exceeds the previously published designs [2]. While the first results are encouraging, a lot remains to be done to validate its potential for wave refocusing in a non-stationary medium.

In this internship/PhD project, the time-reversal figures of merit such as its bandwidth, latency time, and fidelity will be the figures of merit that we will have to study and optimize. Spectroscopic characterizations of the rare-earth doped crystal will be necessary to identify the fundamental limits to these parameters. The final validation of the architecture will include testing our time-reversal processor on RF signals in a reverberating cavity available at Institut Langevin.

The student will have the opportunity to manipulate frequency agile laser sources, optic and optoelectronic components as well as cryogenic equipment.

[1] A. Louchet-Chauvet, Analog time-reversal of optically-carried RF signals with a rare earth ion-doped processor with broadband potential, 2018 International Topical Meeting on Microwave Photonics (2018)
[2] H. Linget, L. Morvan, J.-L. Le Gouët and A. Louchet-Chauvet, Time-reversal of optically-carried radiofrequency signals in the microsecond range, Optics Letters 38, 643 (2013).

Condensed Matter Physics:	YES	Soft Matter and Biological Physics:	NO
Quantum Physics:	YES	Theoretical Physics:	NO