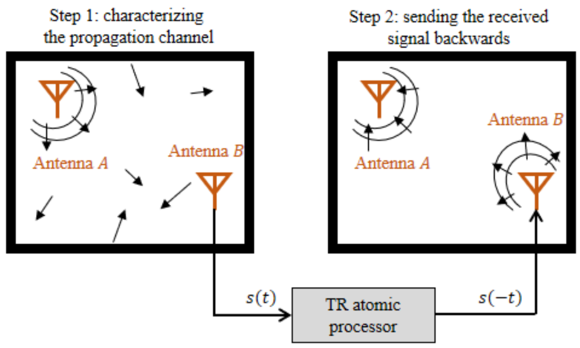
PhD thesis proposal

Analog time reversal processor for radiofrequency signals

Keywords: photon echo, analog signal processing, rare-earth ion-doped crystals

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. When the propagation medium is non-stationary, the transmission channel characteristics keep changing. The time-reversed signal must be sent as quickly as possible, 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. Conversely, **a *fully analog solution*** has the advantage of avoiding this conversion step.



At Institut Langevin, we design original analog architectures for processing optically-carried radiofrequency signals. These architectures rely on a versatile "**atomic processor**" based on light-matter interaction in rare-earth ion-doped crystals cooled down to a few kelvin. In such crystals, one can make the atomic medium emit a light pulse with a controlled temporal shape by using the photon echo process. We recently proposed a modified version of this photon echo sequence that allows the analog generation of the time-reversed copy of an arbitrary waveform. While the first results are encouraging, a lot remains to be done to validate its potential for **broadband RF wave refocusing in a non-stationary medium**.
The goal of this thesis will be to work on improving the performance of this original time-reversal architecture. In particular, the time reversal fidelity, its robustness to phase modulation, the processing bandwidth and the latency time are the figures of merit that will be studied and optimized, in relation to the rare-earth ion-doped crystal spectroscopic properties. A demonstration of time-reversal with real RF signals propagating in a reverberating cavity will be an interesting way to assess the potential of our approach, via the quality of the spatial and/or temporal refocusing.

Techniques/methods in use: Spectral hole burning, stable lasers, closed-cycle cryostats

Applicant skills: background knowledge in one or several of the following fields: quantum mechanics, optics, light-matter interaction, laser physics and/or condensed matter physics. A taste for experimental physics and teamwork is expected, as well as a good level of English. Basic skills in programming are appreciated (e.g. Matlab).

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