Lab project M2 PPN

Monday & Tuesday from Oct 2025 to March 2026

Title of the project: Perfect temporal reflection in optical fibres

Supervisor(s): Théo Torres

Laboratory / Department / Team: ICB/Photonique/SAFIR

Collaborations: B. Kibler

Summary:

Analogies play a crucial role in physics as they serve as powerful tools for understanding complex concepts, promoting understanding, and fostering creativity. A remarkable analogy is the concept of space-time duality in optics as it allows for the possibility to create temporal reflection [1], the pendant in the time domain to standard reflection from a mirror. Temporal reflections have allowed for the generalisation to the time domain of several spatial phenomena such as waveguiding, focusing and cavities.

The internship will focus on the theoretical and numerical study of **temporal reflection phenomena in optical fibers.** In particular, we will focus on temporal reflection and refraction in a realistic experimental set-up, where the "time mirror" will be created using ultrashort optical pulses, i.e. solitons. We will study the influence of the pulse's shape on the properties of the time mirror [2] and investigate the possibility to have total internal reflection (TIR) in the time domain [3], where the incoming light undergoes complete reflection on the soliton, accompanied by a large frequency shift. Concretely, we will focus on the Non-Linear Schrödinger Equation (NLSE):

$$\frac{\partial A}{\partial z} + \beta_1 \frac{\partial A}{\partial t} + \frac{i}{2}\beta_2 \frac{\partial^2 A}{\partial t^2} = i\gamma |A|^2 A,$$

where β_1 and β_2 are the first and second order dispersion parameters and γ the nonlinear parameter.

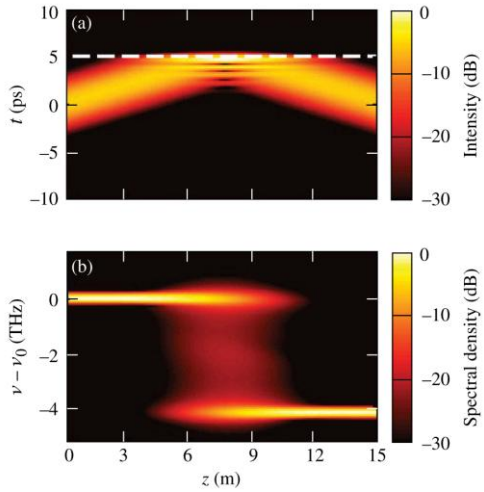

***Figure 1**: Example of total internal reflection*

This project will provide advanced training in nonlinear fibre optics, numerical modelling of spatiotemporal systems, and emerging concepts at the intersection of temporal photonics and wave physics.

References:

[1] G.P. Agrawal, *"Propagation of optical pulses in a spatiotemporal dispersive medium."* Journal of Optics 27.4 (2025)

[2] J. Zhang, *et al.*, *"Impact of the boundary's sharpness on temporal reflection in dispersive media",* Opt. Lett. 46, 4053-4056 (2021)

[3] B. Plansinis, *et al.*, *"Temporal waveguides for optical pulses",* J. Opt. Soc. Am. B 33, 1112-1119 (2016).

Type of project (theory / experiment): Theory

Required skills: Theoretical (Wave Propagation, Nonlinear Fiber Optics) **Numerical** (PDE Solver)