MASTER INTERNSHIP M2 PPN (5 months)

2023-2024

Development of ultrafast fiber laser oscillators delivering high-energy picosecond pulses

Supervisors: Philippe Grelu (Prof.), Aurélien Coillet (Dr.), Mostafa Mohamed (Ph.D. student)

Laboratory / Department / Team : ICB/Photonics Dpt/SAFIR

Collaborations: Uni. Limoges (Dr. V. Couderc)

Summary:

Fiber lasers are in constant development, as they combine numerous advantages, such as high efficiency, excellent beam quality and brightness, flexible cavity design and power scalability. They can be designed to generate ultrashort pulses with applications in medicine, spectroscopy, LIDAR, material processing and so on. Ultrafast fiber lasers also constitute a unique platform to test a variety of pattern formations and complex dynamics, such as optical soliton molecules and extreme waves [1-3].

By revisiting laser dynamics, it is possible to add more flexibility to the pulsed laser regime: instead of a main laser switch-on button that leads to a fixed laser output pulse train, it is possible to incorporate several control parameters allowing a wide tunability of the pulse features, such as pulse duration, central wavelength, and repetition rate. We are particularly interested in addressing the generation of flexible few-picosecond pulses of high energy from a single oscillator. To achieve these features, which are attractive for the next generation of laser applications, it is necessary to make the best match between soliton dynamics and laser cavity architecture. These advances can include the combination of various fibers and components, such as single-mode and multi-mode optical fibers, within the same laser cavity [4-5].

In practice, the M2 intern will work with a doctoral student in our lab, with the guidance of two professors. The M2 student will participate in the assembly of a novel fiber laser cavity architecture, involving the acquisition of fiber-optic practical techniques (connecting, cleaning, splicing, injection coupling) and experimental test (power transmission, spectral analysis). The search of mode locking signatures will also utilize our ultrafast temporal analysis platform (optical autocorrelation, time-stretch single-shot spectral analysis). The intern will also be involved in the numerical modeling of ultrashort pulse propagation within fiber lasers, to gain understanding of the nonlinear dynamics and its potential for the robust delivery of flexible pulses.

References:

[1] Ph. Grelu & N. Akhmediev, *Dissipative solitons for mode-locked lasers*, Nature Photonics **6**, 84–92 (2012).

[2] Ph. Grelu, *Solitary waves in ultrafast fiber lasers: From solitons to dissipative solitons,* Optics Commun. **552** (2024) 130035. https://authors.elsevier.com/a/1i0Xh6wPvt6HS

[3] Z. Wang, A. Coillet, S. Hamdi, Z. Zhang, Ph. Grelu, *Spectral pulsations of dissipative solitons in ultrafast fiber lasers: period doubling and beyond,* Laser & Photon. Rev. **17**, 2200298 (2023). https://doi.org/10.1002/lpor.202200298

[4] K. Krupa et al. *Multimode nonlinear fiber optics, a spatiotemporal avenue*. APL Photonics **4** 110901 (2019). https://doi.org/10.1063/1.5119434

[5] M. Mohammed, A. Coillet, Ph. Grelu, *Energy-managed soliton fiber laser*, submitted (2023).

Type of project: Experimental (70%) – Simulations (30%)

Required skills: Academic knowledge (master level) in nonlinear optics, ultrafast lasers, fiber optics. Taste for experiments and good practices (observation, procedures, resourcefulness). Programming at least in one of these languages: C++ / Python / Matlab.