Proposition de thèse / PhD Thesis proposal
Financement envisagé : MESRI
Contexte collaboratif international : dépôt de projet ANR 2021 PRCI France-Russie
Participation : EUR Recherche excellence 2020, volet « SMILE-SPUTNIC »

Title: **Ultrafast lasers enhanced with artificial intelligence**
Supervisors: Ph. Grelu and E. Hertz

Summary:

Mode-locked fiber lasers represent a growing technology, with successful deployment in numerous areas such as material processing, medicine, telecom and spectroscopy. They also make a versatile workbench for fundamental research, since wide range of complex dissipative soliton dynamics can be studied within tabletop laser setups. Yet, commercial laser systems are mainly thought to deliver fire a factory-fixed laser output. While this is convenient for many applications, there is a huge avenue of research to enhance the number of laser output parameters that can become adjustable by the end-user.

We have recently introduced the approach of laser operation control through genetic algorithm optimization in the feedback loop of the laser cavity [1,2]. The method allows an automatic search of pulsed regimes fulfilling specific target objectives, by actuating simultaneously several cavity degrees of freedom. This new paradigm of laser control through advanced machine-learning strategy is currently stimulating research at the international level [3,4]. The development of the next generation of ultrashort fiber laser sources is anticipated, which will have a huge versatility in terms of pulse profile, spectral coverage, and energy scalability, thus meeting an extended range of applications.
In this project, we shall extend our method to the control of a larger number of degrees of freedom. This includes notably the generation and control of spatiotemporal laser dynamics, with the inclusion of multimode fibers within the laser cavity [5,6]. Indeed, the recent use of multimode fibers within ultrafast lasers unveils a rising paradigm, where nonlinear processes such as beam self-cleaning can promote a wealth of spatiotemporal pulses and patterns, overcoming the adverse effects of the intermodal dispersion

The PhD student will participate in the implementation of several fiber laser architectures, with advanced real-time characterization in spectral and spatial domains. This project includes computer interfacing between the laser output characterization and the intracavity degrees of freedom controlled via artificial intelligence algorithms. The project is multidisciplinary, experimental and numerical, and will benefit from national and international collaborations, with Novosibirk State University, University of Roma, and University of Limoges.

[1] U. Andral et al. "Fiber laser mode locked through an evolutionary algorithm," Optica **2**, 275-278 (2015).
[2] J. Girardot et al. "Autosetting mode-locked laser using an evolutionary algorithm and time-stretch spectral characterization" IEEE J. Selec. Topics Quant. Electron. **26**, 1100108 (2020).
[3] R. Woodward et al. "Towards smart lasers: self-optimization of an ultrafast pulse source using a genetic algorithm," Scientific Reports, 6:37616 (2016).
[4] G. Pu et al. "Intelligent control of mode-locked femtosecond pulses by time-stretch-assisted real-time spectral analysis" Light: Sci. Appl. **9**, 13 (2020).
[5] Wei, X. et al. Harnessing a multi-dimensional fibre laser using genetic wavefront shaping. Light: Science & Applications 9:149 (2020).
[6] Ph. Grelu "Smart lasers tame complex spatiotemporal cavity dynamics" News and Views, Light: Sci. Appl. 9:188 (2020).