Thesis proposal (2020-2023) at ICB/Photonics Department:
Ultrafast multimode fiber lasers

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, crystals, extreme waves (optical rogue waves) – a fundamental research area where we have a leading expertise [1,2].

Until recently, it was thought that ultrashort pulse generation required a laser cavity operating in a single transverse mode. The reason is that the large intermodal dispersion looks incompatible with maintaining over successive cavity roundtrips a coherent and ultrashort beam profile. Very recent investigations [3] showed that specific conditions do allow mode locking with a few transverse modes. These new findings entail important applications, such as increasing the power range of compact ultrafast lasers. They also bring new investigation tools to a fascinating area of fundamental research, namely *ultrafast spatiotemporal dynamics*. This area, which has typically been the ground of laser filamentation involving complex and bulky experimental systems, is now open for a more systematic investigation using the versatile and convenient fiber laser platform. In this project proposal, by using multimode ultrafast fiber laser cavities, we anticipate to explore a full new range of spatiotemporal dynamics, from coherent pulse states to chaotic ones. Coherent pulse states include transverse multimode locking, multimode beam cleanup [4], as well as the formation of spatiotemporal soliton molecules.

Therefore, the aim of this thesis is to develop experimentally multimode ultrafast fiber lasers, as well as to implement the spatiotemporal characterization techniques required to investigate new physical phenomena, such as complex pattern formations. Our fiber laser lab is well equipped to build various laser architectures and perform ultrafast optical characterization. However, multimode ultrafast lasers represent a new activity, which is attracting an increasing focus from the international research scene. This thesis will start in the frame of the development of national and international collaborations, such as with University of Limoges, France, University of Novosibirsk, Russia, and University La Sapienza of Rome, Italy.

Philippe GRELU – Professeur
9 Avenue Alain Savary, B.P. 47870 - 21078 DIJON Cedex – France
Tél (+33) 3 80 39 60 15 – philippe.grelu@ubfc.fr
Secrétariat : Tél. (+33) 3 80 39 60 23 – Fax (+33) 3 80 39 59 71

The candidate should have a taste for fundamental experimental physics, with a good background in photonics, ideally in ultrafast lasers and fiber optics. Teamwork is an important aspect, which includes interaction with international collaborators, and discussion with specialists of numerical simulations and theoretical nonlinear dynamics. Numerical simulation and/or interfacing skills will be a bonus.

References

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

[2] Z. Wang et al., *Optical soliton molecular complexes in a passively mode-locked fibre laser*, Nature Communications 10, 830 (2019).

[3] L. Wright et al., *Spatiotemporal mode-locking in multimode fiber lasers* Science 358, 94–97 (2017).

[4] K. Krupa et al. *Spatial beam self-cleaning in multimode fiber*, Nature Photonics 11(4) (2017).

Supervision: Prof. Philippe GRELU and Dr. Aurélien COILLET

UNIVERSITÉ DE BOURGOGNE

Philippe GRELU – Professeur
9 Avenue Alain Savary, B.P. 47870 - 21078 DIJON Cedex – France
Tél (+33) 3 80 39 60 15 – philippe.grelu@ubfc.fr
Secrétariat : Tél. (+33) 3 80 39 60 23 – Fax (+33) 3 80 39 59 71