New characterization methods for ultrashort laser pulses

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Mode-locked lasers deliver pulses of duration in the femtosecond range (10^{-15} s). Their development in the mid-1960s opened up a broad range of applications, taking advantage of the short pulse duration, the high peak intensity achievable or the wide spectral width. Among the field of applications, one can cite the time-resolved spectroscopy, the nonlinear microscopy, the refractive surgery, the nonlinear optics, the telecommunication applications or the optical metrology (J.L Hall and T.W. Hansch, Nobel price in physics in 2005)…

In all these applications, the pulse duration and pulse shape are critical parameters for the outcome so that the utilization of such pulses requires a comprehensive characterization of the electric field. The emergence of this class of lasers led therefore to a growing interest in reliable and versatile diagnostic tools which represents a difficult task since the pulses are significantly shorter than any photodetector response time. The need of metrology has increased along with the development of new sources at different wavelengths and their applications. Several methods (see review [1]) providing an estimation of the pulse duration as autocorrelation method or a complete characterization of the pulse as FROG or SPIDER devices have been developed. However, most of these methods remain rather complex for a daily use and feature some limitations (spectral range, incident energy, etc...). As a result, there is still a need for simple methods enabling self-referenced and single-shot measurement of weak pulses especially at exotic wavelengths.

Our group has developed with years an expertise in this field with the development of various characterization methods and some industrial partnerships [2-4]. The aim of this PhD is to develop and evaluate original characterization tools based on new concepts. We are working for instance on a new method using a simple optical element and a camera in which two-photon absorption signal takes place [2] so as to provide a "time-resolved optical gating" measurement. This original strategy should offer a complete characterization of ultrashort pulses in a very simple way which has no equivalence in current devices. Several other architectures or process will be investigated.

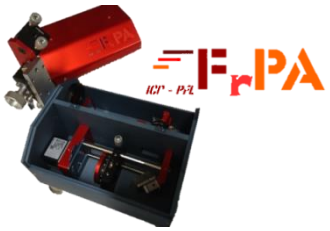

Fig1: Example of characterization device developed in the PFL group and called BOAR [2].

The PhD will be hosted in the Photonics Department of ICB lab. All the necessary equipment for the project will be made available to the student. In particular, our group has 2 femtosecond laser chains (100 fs and 35 fs duration) of tunable wavelength and 2 pulse shaper devices enabling a control of the pulse shapes. The team also has some experience regarding the development of such projects including the design of device or useful numerical simulations.

The work features a substantial experimental content but the student will also be in charge of numerical simulations. A small part of the experiments could be conducted at the University of Strasbourg. The expected results are twofold: publications in peer reviewed journals and filing of patents. In addition to academic opportunities, the thesis will offer a substantial background for possible outlets in industry.

[1] I .A. Walmsley and C. Dorrer, Advances in Optics and Photonics 1, 308–437 (2009)
[2] F. Billard et al, Review of Scientific Instruments 90, 063110 (2019);
[3] P. Béjot et al, « Doppler effect as a tool for ultrashort electric field reconstruction » to be published in Opt. Letters (2020), arXiv:2003.01421 (2020)
[4] patent: “Device and method for characterizing a femtosecond laser pulse” n° FR 3 034 577