Lab project M1 PPN & QuanTEEM

04/05/2026 – 19/06/2026

Title of the project: Ultrafast metrology by plasma-induced frequency resolved optical switching.

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Laboratory / Department / Team : ICB / Photonic / PFL

Collaborations:

Summary:

The development of mode-locked lasers in the mid-1960s gave rise to the challenge of measuring ultrashort optical pulses, whose durations—typically in the femtosecond range (1 fs = 10^{-15} s)—are far shorter than the response time of any available photodetector. The need for accurate ultrafast metrology has grown steadily alongside the emergence of novel laser sources operating across a wide range of wavelengths and finding applications in numerous fields. As a result, several pulse-characterization techniques have been developed.

Our group has well-established expertise in this area, including the development of several characterization methods and sustained collaborations with industrial partners. Recently, we introduced a novel technique named PI-FROSt (Plasma-Induced Frequency-Resolved Optical SwiTching) [1]. PI-FROSt relies on probe-beam defocusing induced by a plasma lens. In this approach, a plasma is generated in a gas through non-resonant multiphoton ionization by a moderately intense pump pulse. For a bell-shaped pump beam, the resulting plasma density distribution acts as a divergent lens. A probe pulse propagating through this low-density plasma is defocused, leading to an increase in its far-field beam size. The diffracted portion of the probe, isolated using a spatial filtering technique, is recorded with a spectrometer as a function of the pump–probe delay. The resulting spectrogram enables complete retrieval of the probe pulse's temporal and spectral characteristics. This method offers several key advantages. The switching mechanism, based on plasma, is both highly precise and robust, free from phase-matching constraints, and operable over an exceptionally broad spectral range. We have thus demonstrated [2] the PI-FROSt characterization of radiation spanning nearly 2.6 octaves (from 0.6 to 3.2 µm), representing a record in this spectral domain. The technique also allows in situ measurements at the beam waist with no intrinsic damage threshold, and supports both self- and cross-referenced measurements using pump and probe pulses at the same wavelength.

In this project, we aim to assess the potential of this approach for the metrology of weak field pulses particularly in the UV spectral range. Different architectures will be explored to reduce the pump energy required to generate a measurable signal. First, the method will be evaluated in gas phase using systems with low ionization potential (IP) with UV pulses. In parallel, alternative approaches based on plasma generation within a solid-state semiconductor will be investigated. This strategy is expected to significantly lower the required pump energy, thereby making the technique particularly suitable for the characterization of weak laser fields.

[1] R. K. Bhalavi et al, Opt. Lett. 49, 1321-1324 (2024) / P. Béjot et al, Adv. Photonics Res., 2024, 2400074
[2] P. Béjot et al, Opt. Laser Technol. 190, 113039 (2025)

Type of project (theory/experiment): mainly experimental

Required skills: optical alignment