Internship M2 PPN

from 2026 April 1st to 2026 July 31th

Title of the project: Plasma-induced frequency resolved optical switching in solid-state target

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Laboratory / Department / Team: ICB / Photonic / PFL

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 world 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.

One limitation of the current implementation is the requirement for a relatively high pump pulse energy (on the order of several tens of microjoules), which may be incompatible with certain applications. In this project, we propose to explore an alternative approach in which the plasma will be generated within a solid-state semiconductor, such as a ZnSe substrate. Different configurations will be investigated, including pumping in the linear absorption regime with a pump wavelength within the semiconductor's absorption band, as well as pumping wavelength below the bandgap to generate free carriers via nonlinear processes. This strategy is expected to significantly reduce the required pump energy, making the technique well suited for the characterization of weak laser fields, particularly in the infrared spectral region.

This internship may lead to a PhD position funded by an industrial partner.

[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