# ***INTERNSHIP PROPOSAL***

Laboratory name: Laboratoire d'Optique et Biosciences
CNRS identification code: UMR 7645
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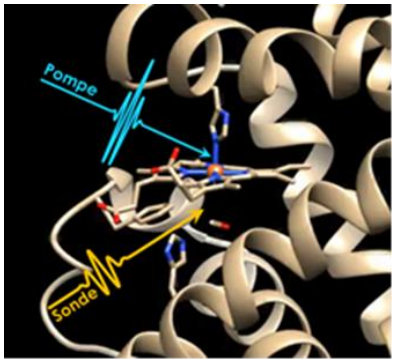
Internship location: LOB, Ecole Polytechnique, Palaiseau

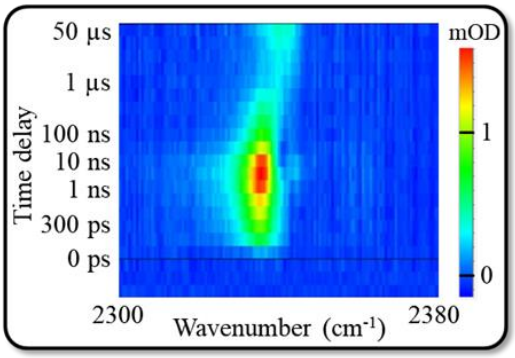
Thesis possibility after internship: YES
Funding: NO. But 2025 ANR grant submitted and possible application to ED IP Paris

**Multiscale mid-infrared femtosecond spectroscopy in proteins**

Laboratoire d'Optique et Biosciences benefits from a cross-disciplinary environment where physicists and biologists work together in order to address relevant issues in biology through the development of new optical methods, based for example on femtosecond lasers and nonlinear optics. In this context, the host team is more particularly developing femtosecond spectroscopy in the mid-infrared (mid-IR) and visible spectral domains in order to control and probe biomolecules [1, 2]. In collaboration with Laboratoire Charles Fabry and the Amplitude company, we have recently developed a 100-kHz femtosecond mid-IR source combined with high-resolution spectroscopy [3].

The dynamics of a biochemical reaction can be investigated using the pump-probe method. As shown below on the left, a visible pump pulse triggers the reaction, here by exciting the heme cofactor in a hemoprotein, thereby dissociating the ligand, carbon monoxide (CO) in this case. After a certain amount of time, called the pump-probe delay, a mid-IR probe pulse is absorbed by the CO molecular vibration and the resulting absorption spectrum is measured. We have developed a unique method allowing to control the pump-probe delay from femtosecond to millisecond timescales [4], which allows to address the multiscale nature of the dynamics commonly encountered in biochemical reactions. The figure below on the right shows an application of this method to the photoenzyme fatty acid photodecarboxylase [2]. The observed dynamics extends from picosecond to microseconds and could not have been observed using conventional methods.




The purpose of the proposed project is to apply this new method combined with high-resolution mid-IR spectroscopy to monitor the motion of a carbon-monoxide ligand inside hemoglobin over the entire biologically-relevant timescale, in order to understand the key role of the protein structure in its functions.

[1] V. Kemlin, A. Bonvalet, L. Daniault, M. Joffre, J. Phys. Chem. Lett. **7**, 3377 (2016).
[2] D. Sorigué et al., Science **372**, eabd5687 (2021).
[3] M. Jonusas *et al.*, Opt. Express **32**, 8020 (2024).
[4] L. Antonucci, X. Solinas, A. Bonvalet, M. Joffre, Opt. Express **28**, 18251 (2020).

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| Condensed Matter Physics: | YES | Soft Matter and Biological Physics: | YES |
| Quantum Physics: | YES | Theoretical Physics: | NO |