Title : Mid-infrared femtosecond spectroscopy in proteins

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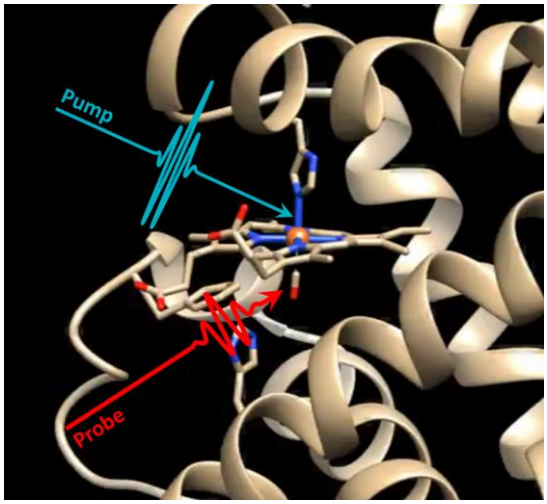
Research Area : Optics and biophysics

Methods: femtosecond lasers, nonlinear optics, femtosecond spectroscopy

PhD track subject :

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) in order to control and probe molecular vibrations in biomolecules [1-3]. The available experimental setup consists of a 1-kHz source of femtosecond mid-IR pulses, relying on an amplified Titanium:Sapphire laser system pumping two nonlinear optical stages.



The dynamics of a biochemical reaction can be investigated using the widespread pump-probe method. As shown in the figure above, 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. In the standard approach, the pump-probe delay can be varied by changing the optical path travelled by the probe beam before being focused on the sample. Although highly efficient, this approach suffers from a delay range limited to a few nanoseconds considering the practical length of a physical delay line. In order to overcome this limitation, we have developed the ADASOPS method, relying on two different femtosecond lasers for generating the pump and probe pulses, allowing to scan the pump-probe delay over ten orders of magnitude, from picoseconds to milliseconds [4-5].

Our current projects deal with the application of this method to the multi-timescale dynamics of a variety of proteins, as well as with the application of multidimensional femtosecond spectroscopy in order to unravel protein structure fluctuations.

References :

[1] P. Nuernberger, K.F. Lee, A. Bonvalet, L. Bouzhir-sima, J.C. Lambry, U. Liebl, M. Joffre, M.H. Vos, J. Am. Chem. Soc. **133**, 17110 (2011).
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[4] X. Solinas, L. Antonucci, A. Bonvalet, M. Joffre, Opt. Express **25**, 17811 (2017).
[5] L. Antonucci, X. Solinas, A. Bonvalet, M. Joffre, Opt. Express **28**, 18251 (2020).