PhD program:

Ultrafast light energy conversion at the molecular scale.

Contact: Jérémie Léonard, directeur de recherche
Institut de Physique et Chimie des Matériaux de Strasbourg, IPCMS
Département d'Optique ultrarapide et Nanophotonique (DON)
Tel : +33 (0)3 88 10 72 43. E-mail : Jeremie.Leonard@ipcms.unistra.fr

The molecular scale has become the relevant scale to design new functional materials. This is exemplified by the development of organic materials for solar energy conversion into electrical (e.g. organic solar cells) and chemical (photocatalysis) energy, or nano-devices called molecular motors [1] that convert light energy into mechanical energy and realize a function at the molecular scale. In many cases, the design of such light-responsive molecular devices is guided by natural examples which perform similar tasks with outstanding efficiency, such as chromophore-protein complexes for sun-light harvesting in photosynthetic organisms, or in the biological process of vision.

In such (bio) molecular systems, the light energy conversion is performed by photo-induced chemical reactions, also called "photoreactions". In a photoreaction, the absorbed photon promotes the electrons of the molecule in an excited state. In response to this, the nuclei of the molecules enter in motion, and a reaction occurs and produces a new molecular state, i.e. the photoproduct. Also, in condensed phase, part of the photon energy is dispersed to the environment (e.g. the solvent for molecules in solution). All these physical processes contribute the so-called photoreaction. They typically occur on the picosecond time scale or faster. **Understanding such photophysical processes** is of fundamental interest in the view of designing light-responsive molecular devices with optimum performances.

We investigate these ultrafast photophysical processes in molecules by using ultrashort (femtosecond = 10^{-15} s) UV-Vis laser pulses to excite and interrogate molecular systems along the time course of their photoreaction. This experimental approach is called **time-resolved spectroscopy** and requires experimental developments using fs laser pulses (see e.g. 2018 Nobel Prize for physics), and implementing non-linear optics.

In this context, we propose a PhD program on the experimental investigation of ultrafast **light-to-mechanical energy conversion** in synthetic molecules designed to reproduce the photoreaction that triggers the process of vision in the rhodopsin protein [1,2], and applicable to the design of molecular rotary motors. Upon light excitation these molecules decay to the ground state by rotating around a C=C double bond, a process called photoisomerization. Here we are interested at understanding the mechanism which controls the photoreaction and its efficiency.

The PhD student will (1) use state-of-the-art spectroscopy set-up for femtosecond-resolved absorption spectroscopy with sub-10fs laser pulse duration do investigate the photoreactivity of a variety of molecular motors within a collaborative ANR project involving other partners for chemical synthesis (new molecular motors design) and theoretical modeling. He/She will also (2) contribute the further development of a new ultrafast spectroscopy approach, co-called 2-dimensional UV-Vis spectroscopy, to explore its application to the investigation of ultrafast photoreactivity in general, and of molecular-level light-to-mechanical energy conversion in particular.

[1] Feringa, B.L. Nobel Lecture: The Art of Building Small, from molecular switches to motors, 2016.
[2] M. Gueye, et al., "Engineering the vibrational coherence of vision into a synthetic molecular device", Nat. Commun. (2018) **9**,313.