# *INTERNSHIP PROPOSAL*

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Thesis possibility after internship: YES
Funding: YES type of funding: ANR funding already obtained

## Mimicking photosynthesis for room-temperature quantum optics and optimized energy conversion

In order to maximize the absorption and harvesting of photons towards photochemical reaction centres capable of splitting water into chemical fuels, Nature has performed an impressive quantum engineering of photosynthetic pigments, also called light harvesting complexes (LHCs). In these complex 3D arrangements of chlorophyll and carotenoid molecules (an example is given in Figure 1-a), templated by proteins, quantum transition dipoles are coherently coupled in a strong coupling regime leading to optimized absorption cross-sections and allowing spectral tuning covering the red to near-infrared range. Spectrally matched LHCs are then weakly coupled (by FRET) in order to efficiently harvest light towards reactions centres at sub-nanosecond timescales. Interestingly, this strong coupling regime between molecules in LHCs significantly increases the temporal coherence of these quantum emitters, making them compatible with quantum technologies working at room temperature instead of tedious and cost-intensive cryogenic conditions.

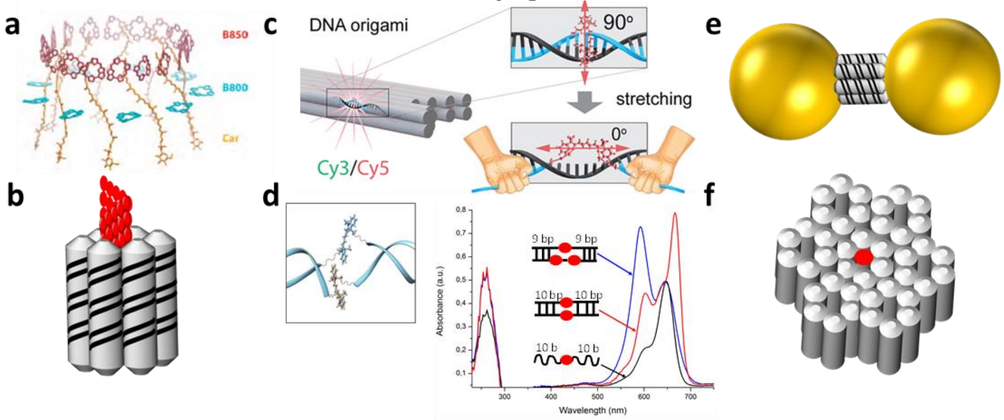


*Fig. 1: Natural (a) and biomimetic (b) photosynthetic pigments (made of DNA double-helices templating cyanine molecules). (c) Control of the position and orientation of cyanine dyes with DNA (ref). (d) Strong coupling between cyanine dyes on DNA (ref). Biomimetic LHCs integrated in an optical resonator made of gold nanoparticles (e) or assembled with a reaction centre for artificial photosynthesis (f).*

The aim of this project is to develop a new family of biomimetic photosynthetic pigments by substituting the protein template of LHCs with an artificial DNA nanostructure (also called DNA origami) and the chlorophyll molecules by synthetic cyanine dyes (Figure 1-b). The interest of this substitution is three-fold: (i) DNA nanostructures can be designed in any chosen geometry in which the position and orientation of cyanine molecules can be controlled with sub-nanometre precision (1-c) ; (ii) cyanine dyes can be strongly coupled together in DNA (1-d) ; (iii) DNA nanostructures can be readily coupled to optical resonators in order to observe coherent light-matter interactions at room temperature (1-e). By controlling the number of coupled cyanine molecules but also the strength of their coupling, we will produce new building blocks for artificial photosynthetic systems in which energy harvesting is optimized over the entire visible range (1-f) but also optimized quantum emitters for coherent light-matter interactions at room temperature when coupled to an optical resonator (1-e).
The group of Sébastien Bidault at Institut Langevin is specialized in the development and study of hybrid emitter-resonator systems using DNA (Nature Commun. 2012) up to a strong coupling regime (ACS Nano 2021). The project will be performed in collaboration with the group of Gaëtan Bellot at CBS in Montpellier, experts in the design of complex DNA architectures (Nature 2017).

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| Condensed Matter Physics: | YES | Soft Matter and Biological Physics: | YES |
| Quantum Physics: | YES | Theoretical Physics: | YES |