Master in Photonics – "PHOTONICS BCN"
Master ERASMUS Mundus "EuroPhotonics"

MASTER THESIS PROPOSAL

Dates: April 2023 – July or September 2023

Laboratory: **Molecular NanoPhotonics – Niek van Hulst group**
Institution: **ICFO**
City, Country : **Castelldefels - Barcelona**

Title of the master thesis:
"Light to charge: photo-current detection of excited state energy flow"

Name of the master thesis supervisor and co-supervisor:
(for external proposals a co-supervisor from the Master program is needed)
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Keywords :

- fs laser spectroscopy, nanoscale microscopy, transient spectroscopy, superresolution tracking, light-harvesting membranes, photocurrent detection, exciton transport, energy hopping, (de)coherence

Summary of the subject (maximum 1 page) :

We will track the photon-to-electron conversion in light-harvesting complexes, through antenna reaction center complex, by electric read-out. To detect the photo-induced current you can choose one of two complementary techniques: (i) 2D-material devices and (ii) electrochemical detection. The graphene ultrafast photo-thermoelectric response will allow tracing the ps dynamics, potentially at few protein levels. The photo-electrochemical current will allow quantifying the charge separation rate and photon-to-electron efficiency.

For the 2D-materials device, we will explore ultrafast photocurrent detection both in bare and hexagonal boron nitride (hBN)-encapsulated graphene. The devices will be fabricated in collaboration with the groups of Tielrooij (ICN2-Barcelona) and Koppens (ICFO-Barcelona), both specialized in 2D-materials. Using our broadband laser and pulse shaper we have already found the photovoltage generation time to be faster than 50 fs due to efficient electron heating. The several-nm-size LH-complex, and even more a membrane will dramatically affect the photocurrent response. Interestingly the light-harvesting and reaction centre complex will experience fast ps quenching of the exciton, but also rapid transfer of the created

charge, both in competition with each other. Therefore, tuning of the device layout, spacer layer and thickness will be important to control the competitive decay channels. The idea is to determine the photovoltage spectrum by tuning through the light-harvesting complex excitation band, and by controlling the back-gate voltage of the graphene device. To this end we will use broadband Fourier excitation spectroscopy and at the same time verify the ultrafast and non-linear response.

For the electrochemical approach we will functionalize gold electrodes with photosynthetic complexes, remaining functional, connected via self-assembled monolayers (SAM) and oriented such that the luminal side is exposed to the electrolyte. We will team-up with the group of Pau Gorostiza (IBEC-Barcelona) expert in photo-electrochemistry. The photo-induced current between the photosystem and a counter electrode can reach nA level, relative to a reference electrode. The idea is to determine the photovoltage spectrum by tuning through the light-harvesting complex excitation band, inside a microfabricate cell with integrated electrodes and push the dynamic response to the sub-microseconds.. To this end we will use broadband Fourier excitation spectroscopy and at the same time verify the ultrafast and non-linear response.

Additional information (if needed):
Required skills:
Exact Sciences or Physics or Engineering or Nanotechnology or Physical Chemistry.
Interest in experimental research, nanotechnology, sensitive imaging and detection.
Assertiveness and group spirit.

Training outcome:
- Skills: nanofabrication, nanocontrol, single particle detection, super-resolution, ultrafast detection, pulse lasers,
- Insight: advanced imaging, inferometric sensing, Fourier imaging, shot-noise limit of detection, single particle detection.....
- Getting prepared for a PhD project and position;
- Report of master project culminating in a publication.