Master or Bachelor Project - Strong light matter interaction to manipulate singlet fission in photovoltaic materials

When light is absorbed by an organic semiconductor, an electron hole pair (exciton) is created. Understanding and controlling these states is very important for optoelectronic applications. Some materials have the remarkable property that one excited (bright) singlet exciton can split into two (dark) triplet excitons. This process is called singlet fission. Singlet fission can enhance the efficiency of solar cells, by creating two energy carriers out of one photon. To achieve enhanced photovoltaic performance, it is important to have efficient singlet fission.

In this project we will investigate how the singlet fission rate can be influenced by strong light-matter interaction. When an excitonic material is put in an optical cavity with the electromagnetic mode tuned to the energy of an exciton, the two modes interact and influence each other. When the interaction is strong enough this leads to the formation of two new modes, called polaritons. These polaritons have partial photonic and excitonic character. This hybrid character can have a large influence on many properties of the excited states in the material, such as the effective mass, delocalization of the wave function and energy levels. As the coupling only affects the bright states and not the dark states, one can tune singlet energy with respect to the triplet energy. ***The goal of this project is to investigate how the tuning of these two levels may affect singlet fission.***

During this project you will do simulations on the properties of polaritons in a plasmonic array of nanoparticles defining an optical cavity. You will have to design and characterize systems that support exciton-polaritons and investigate the properties of the hybrid material using advanced nanophotonic techniques.

If you're interested or would like to have more information, please contact:

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Strong coupling can be described as follows: when a photon interacts with a material with an excitonic transition close to the photon energy, the photon can be absorbed and create an exciton. After a while this exciton will decay back to the ground state and may emit a photon again. Usually this emitted photon will be lost for the system, however when the material is placed into a cavity the emitted photon has a lower probability of leaving the system and may be absorbed again.

This interaction process can repeat times on a very short time scale.

where the emitted photon can be 'trapped'

Interaction

In this project the interaction of excited states in organic materials with plasmonic resonances in a nanoparticle array

Singlet fission is a process where an excited spin 0 ↑↓⟩ splits in two triplet states

Interactions between excited states and electromagnetic modes in optical cavities

The exciton and the electromagnetic mode can both be described as a harmonic oscillator. When these two oscillators interact in an optical cavity, this leads to a modification of the Eigen-frequencies of the two oscillators. If the interaction is strong enough two new modes , called exciton-polaritons, can be described by a superposition of the two constituting modes, they have partial photonic and excitonic character. This may have large influence on many properties of the excited states in the material, such as the effective mass, delocalization of the wave function and energy levels.

In this project the goal is to investigate the transport properties of these polaritons, as they are very interesting for future applications in organic optoelectronic devices. You will do simulations on the properties of polaritons in a plasmonic array of nanoparticles. You'll have to design and characterize systems that support plasmon-exciton-polaritons. You will help to build a transient absorption microscope to measure the properties of the created exciton polaritons.

Bachelor Project

Manipulating Photophysics in Tetracene Crystals with Strong Light-Matter Coupling

Add a full list of authors although we will ask for a talk

Organic semiconductors are functional materials that constitute the core of organic optoelectronic devices, such as organic LEDs (OLEDs) and organic photovoltaics (OPVs). For optimal performance, it is necessary to tune the energy levels and the photophysics in the semiconductor. The most obvious way to achieve this tuning is by changing the chemical structure of the molecules. However, it is extremely difficult to change one property without affecting the others. A promising method to selectively change the excitonic energy levels in semiconductors is by interaction with the vacuum electromagnetic field in optical cavities. If the coupling is strong enough, it leads to the formation of new energy levels in the material with partially photonic-excitonic character. Here we show that by applying a tetracene organic crystal on a well-designed plasmonic cavity, we can modify the energy exciton levels in tetracene, leading to new photophysics. In particular, we observe an enhanced singlet emission from triplet fusion. This demonstration illustrates that strong light-matter coupling can become a very powerful tool to design material properties relevant for OLEDs and OPVs.