Center for Excitonics (CE)
EFRC Director: Marc Baldo
Lead Institution: Massachusetts Institute of Technology
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Mission Statement: *To supersede traditional electronics with devices that use excitonics to mediate the flow of energy.*

Exciton - *a quasiparticle excitation consisting of a bound electron and hole that mediates the absorption and emission of light, especially in disordered and low-dimensional materials.*

In this Center, we seek to supersede traditional electronics with devices that use excitons to mediate the flow of energy. Mastering the properties of excitons offers the ability to guide energy at the nanoscale, and transform it with a flexibility that is impossible in conventional systems. Our objectives are to increase the efficiency of solar photovoltaic cells, and to develop new materials and structures for high brightness solid state lighting.

We pursue these goals with three teams.

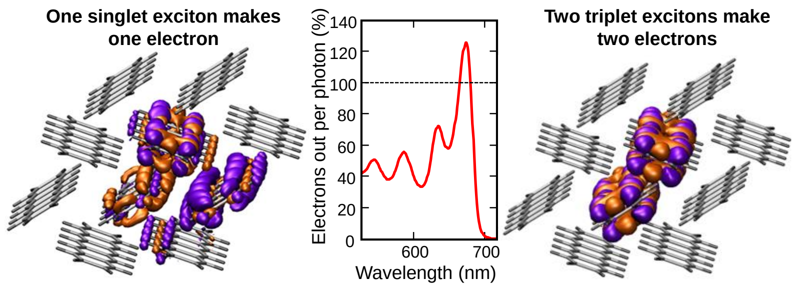

Figure 1. Unlike electrons, excitons can be split. In the Center for Excitonics, we have used singlet exciton fission in pentacene to generate at least 1.26 electrons per photon.

Team 1: Multiexciton Physics & Applications
(*Baldo*, *Bawendi*, *Bulović, Dauler, Willard, van Voorhis*)

Singlet exciton fission is one focus of our fundamental studies of exciton splitting in different materials. In conventional nanocrystalline semiconductors, *Bawendi* and *Dauler* have performed extensive single molecule spectroscopy showing that excitation of secondary electrons must out-compete rapid thermalization losses. But in molecules *Baldo* and *Van Voorhis* demonstrated that these losses are spin disallowed, meaning that exciton fission can be almost perfectly efficient. Our present efforts concentrate on the interface between molecular excitons and inorganic materials, including colloidal nanocrystals. In particular, we seek to couple molecular triplet excitons to silicon. The aim is to sensitize silicon solar cells, doubling the photocurrent from high-energy solar photons (λ < 550 nm), and ultimately boosting power conversion efficiencies to 30% or more.

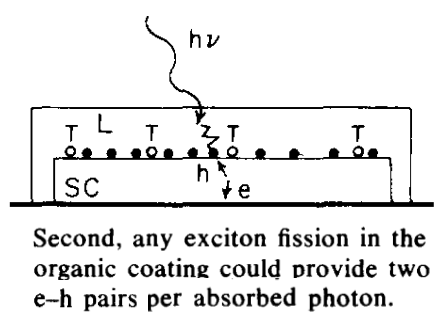

Figure 2. Dexter's 1979 proposal for sensitization of a semiconductor (SC) by an organic layer (L) capable of singlet exciton fission.

Team 2: Excitonic Antennas and Quantum Transport
(Aspuru-Guzik, Bathe, Black, Dincă, Nelson, Schlau-Cohen)

This team is led by *Alán Aspuru-Guzik* and is inspired by photosynthesis. Whereas Team 1 examines localized excitons, this team studies delocalized excited states in molecular assemblies known as excitonic antennas. Light harvesting structures in photosynthesis collect and transport solar radiation in the form of excitons with near unity efficiency using a wide variety of design principles that tailor operation for each organism's environment. Indeed, photosynthesis exploits excitons and exhibits much larger levels of long range disorder than conventional solar cells. Its tolerance of disorder allows photosynthetic 'circuits' to be assembled at low energy cost, and consequently, the energy payback time of a leaf is as short as several days - ~100× lower than conventional solar cells.

Our efforts to understand natural excitonic antennas and fabricate synthetic analogs are broken into four aims:

(i) **Theory** – How do excitonic antennas operate?
(ii) **Spectroscopy** – How can we observe excitonic transport in antennas?
(iii) **Synthesis** – Can we build artificial antennas?
(iv) **Quantum transport** – How can we protect excitons against disorder?

Team 3: Two dimensional Excitonic Crystals
(Jarillo-Herrero, Tisdale, Englund, Kong, Levitov, Li, Nelson, Stach)

This team is led by *Pablo Jarillo-Herrero* and *Will Tisdale*. Crystalline, and just a few atoms thick, the 2D transition metal dichalcogenides (TMD) exhibit the best electronic properties of any known semiconductor while still remaining excitonic at room temperature. This combination of properties is especially attractive for energy applications, especially solid state lighting, where bound excitons enhance luminescence relative to free carrier materials, the outstanding charge transport properties reduce Ohmic losses, and the 2D sheets can be readily integrated with other electronic materials. Scientifically, the material properties of the 2D TMDs are also appealing. They exhibit unique phenomena such as an exceptional dependence on strain, and strong luminescence from trions – formed when an exciton binds with one additional electron or hole and becomes singly charged.

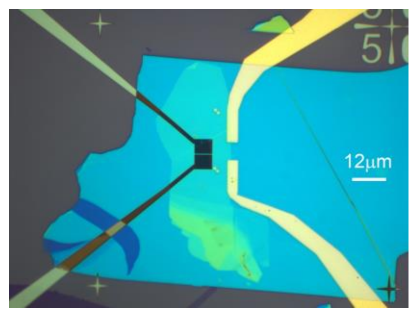

Figure 3. A $MoTe_2$-based LED and solar cell, built by *Jarillo-Herrero*.

Our efforts in this team are divided into four aims:

(i) **2D LEDs and Photovoltaics** – both as scientific platforms and potential applications
(ii) **Energy transfer** – coupling 2D materials to 0D excitonic materials
(iii) **Synthesis** – novel fabrication for improved crystal quality and novel functionality
(iv) **Exciton polaritons** – for long range energy transfer and potentially coherent control

Center for Excitonics (CE)	
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