Research in the Sfeir Lab:
Molecular and Nanophotonic Structures for Optical Energy Conversion

Prof. Matthew Y. Sfeir
msfeir@gatech.edu

Group Information

Our group's research focuses on the discovery of macromolecular and nanoscale materials with unconventional functional properties that can be leveraged in emerging sustainable energy technologies. We specialize in:

(i) the development of non-invasive and high-throughput ultrafast optical, infrared, and terahertz probes to address challenging chemical and materials science problems

(ii) organic and nanoscale materials with strongly interacting electronic, vibrational, and spin degrees of freedom.

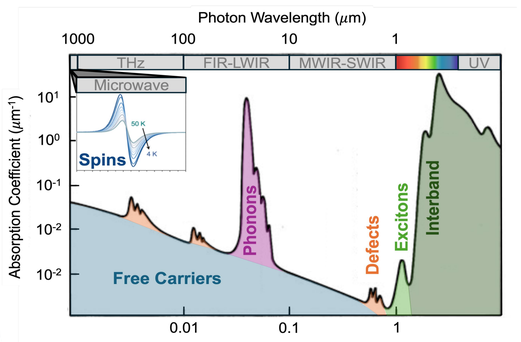
(iii) the design and implementation of nanophotonic platforms that enhance the performance of photophysical and photochemical light harvesting processes

Our highly collaborative science program depends on key partnerships with like-minded researchers engaged in chemical and materials synthesis, modeling and theory, and device fabrication and testing.

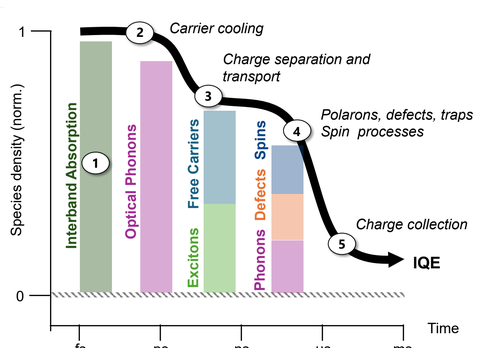
Research and Example Projects

Ultrafast and Nonlinear Optical Probes for Materials Discovery

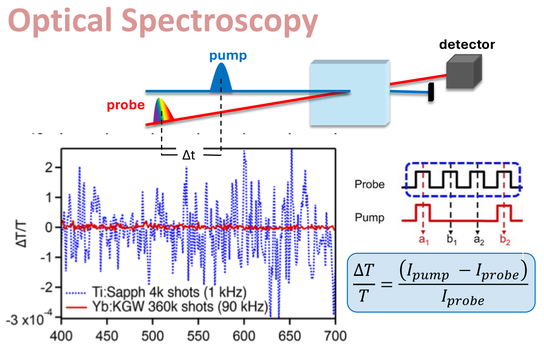
Device relevant light-matter interactions can be identified in the spectral domain…



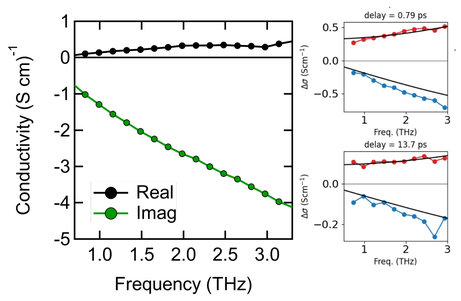
…or in the time domain.



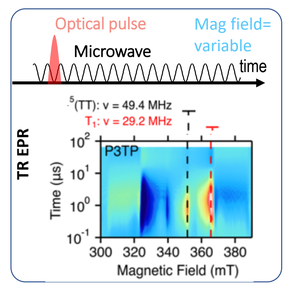
(i) High-Sensitivity Transient Optical Spectroscopy



(ii) Ultrabroadband THz

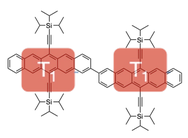


(iii) Coupled Optical-Microwave Methods



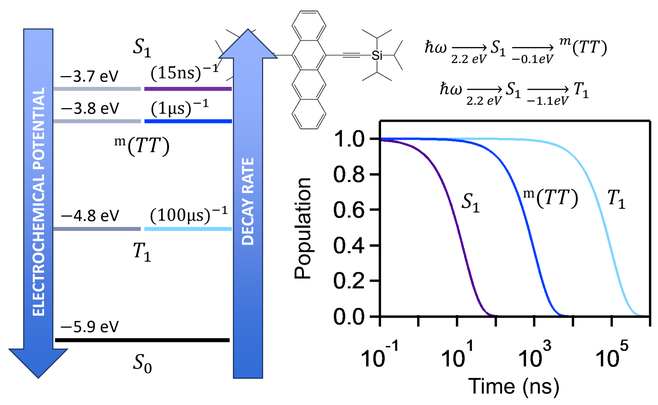
Organic Spin Materials

Singlet Fission Molecules



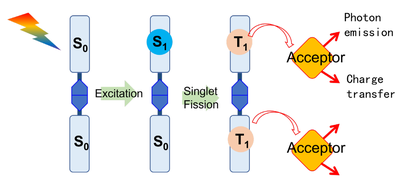
Chromophore 1 (S=1) X Chromophore 2 (S=1) → (Clebsch-Gordan coeffs) → Triplet Pair States: 1 S=0, 3 S=1, 5 S=2

Spin Angular Momentum Addition → Exchange Interactions → Exchange + ZFS (B=0)



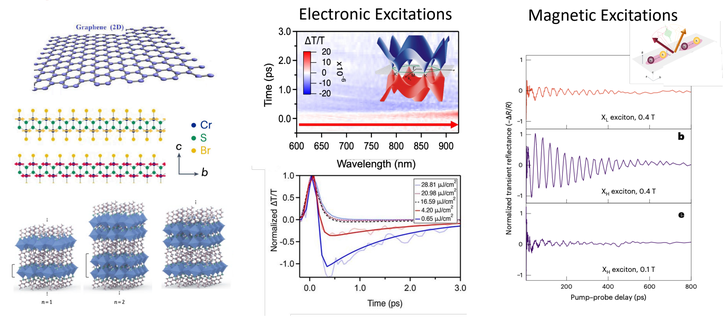
New photochemical paradigms based on triplet pair reactions?

- inherently multielectron
- Delocalized and multireference
- Long lifetimes
- Large potential energies

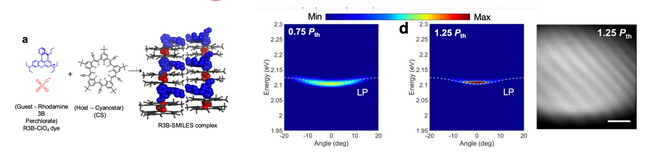


Nonlinear and Quantum Nanomaterials

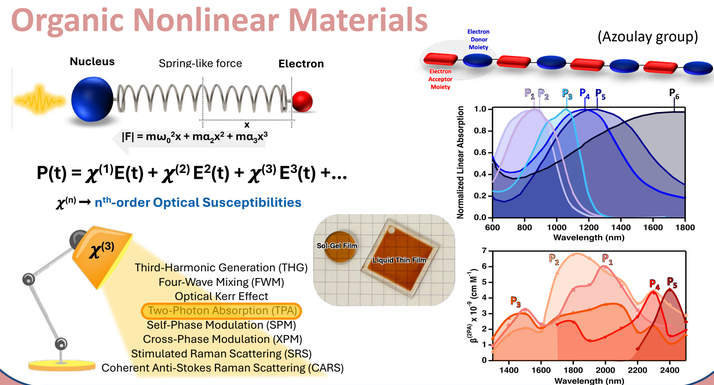
Layered and Quasi-2D Materials



Nanoscale Lasing and Condensation

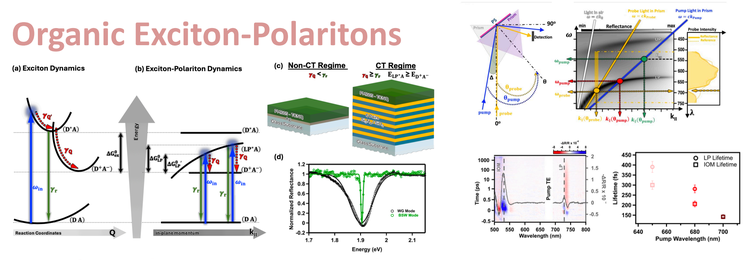


Organic Nonlinear Materials



Nanophotonic Platforms for Photochemistry

Organic Exciton-Polaritons



Semiconductor Metasurfaces

Heterogeneous Photocatalysis

- solid-state semiconductor absorbers
- multielectron photochemistry

Grand challenge…
High efficiency with visible light!

Solution:
tailored interfacial absorption using Mie resonances

$2R \approx \lambda/n$

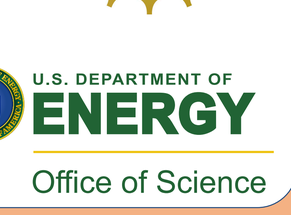
Depletion width:

$W_d = \sqrt{\frac{2\varepsilon}{q} V_O \frac{1}{N_D}}$

Absorption length:

$\frac{1}{\alpha} = \frac{\lambda}{4\pi n''}$

Ratio:



Representative Publications

B. Datta et. al., "Magnon-mediated exciton-exciton interaction in a van der Waals antiferromagnet," Nature Materials, Accepted (2025). https://arxiv.org/abs/2409.18501

Y. Paudel et. al., "Metasurface-enhanced photochemical activity in visible light absorbing semiconductors," Journal of Chemical Physics, 160 144710 (2024).

E. Michail et. al., "Addressing the Dark State Problem in Strongly Coupled Organic Exciton-Polariton Systems," Nano Letters, 24 557 (2024).

S. Hall et. al., "Optimizing the sensitivity of high repetition rate broadband transient optical spectroscopy with modified shot-to-shot detection," Review of Scientific Instruments, 94 043005 (2023).

K. R. Parenti et. al., "Quantum interference effects elucidate triplet-pair formation dynamics in intramolecular singlet-fission molecules," Nature Chemistry, 15 3 339-346 (2023).

G. He et. al., "Direct exciton harvesting from a bound triplet pair," Advanced Materials, 34 2203974 (2022).

Complete list of publications:

Further Information

Georgia Tech
ACS PRF
NSF
ADVANCED SCIENCE RESEARCH CENTER
THE GRADUATE CENTER
CITY UNIVERSITY OF NEW YORK
GORDON AND BETTY MOORE FOUNDATION
U.S. DEPARTMENT OF ENERGY
Office of Science