Exploring Light-Matter Interactions from X-rays to Microwaves

Cushing Lab | *Division of Chemistry and Chemical Engineering*

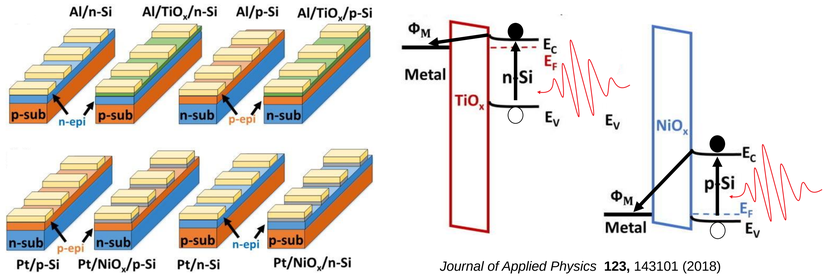
Our Group

We develop spectroscopic techniques that span the microwave to soft X-ray regions and probe dynamics that occur on timescales ranging from femtoseconds to microseconds. Specifically, we have been building a THz pump, XUV probe set-up and an entangled photon interferometer. Additionally, we are working on expanding the scope of our spectroscopic experiments. If you are interested in building optical, mechanical, and vacuum set-ups, developing theory for understanding X-ray and optical data or designing, fabricating, and testing samples, talk to us!

Motivation

Solar Energy

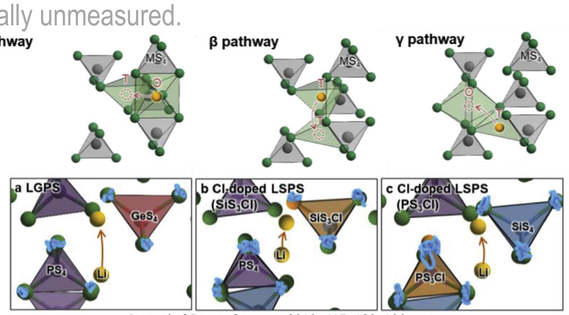
Investigate how the interaction of photoexcited carriers with vibrational modes (phonons) leads to fast relaxation and localization of carriers on sub-picosecond timescales with the aim of improving efficiencies of photovoltaics, photocatalysts and thermoelectrics.



Journal of Applied Physics **123,** 143101 (2018)

Batteries

In solid state ionic conduction, Li ions hop through the atomic scale channels of a solid on picosecond timescales. The resulting electronic and structural correlations are predicted to control ion mobility – but are experimentally unmeasured.

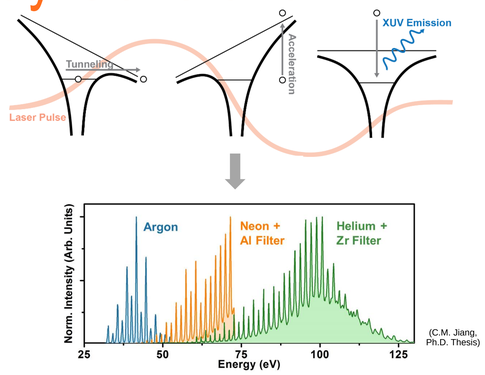


Journal of Power Sources. 2019, 415, 189–196.

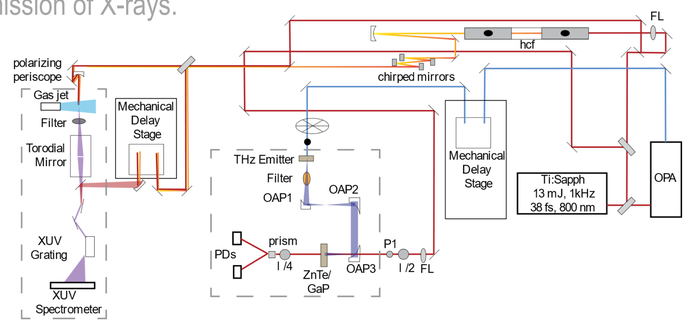
Table-Top X-Ray Generation

HHG Setup

The electric field of a pulsed laser can tunnel ionize electrons in a noble gas. On the down turn of the electric field the ions are accelerated back toward the nucleus, with the collision leading to the emission of X-rays.

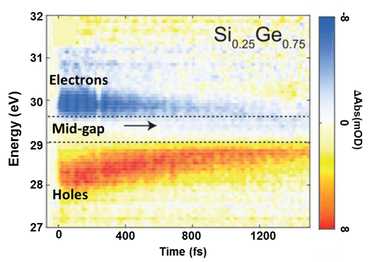


(C.M. Jiang, Ph.D. Thesis)

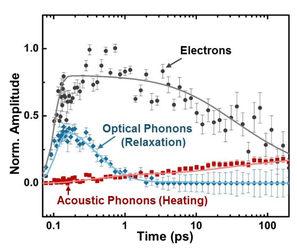


Applications of XUV/soft X-rays

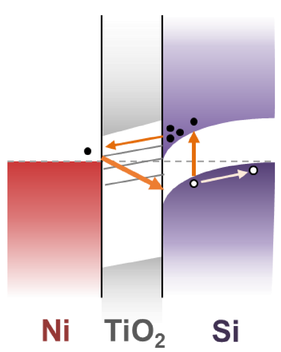
Electron and hole energies

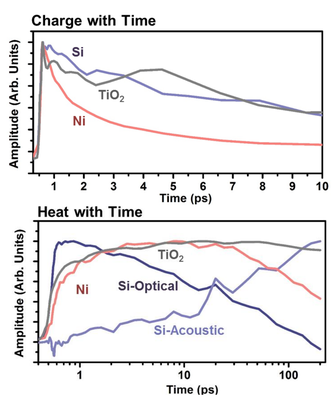


Electron and phonons lifetimes



Expanding the understanding of photoexcited dynamics of solid state materials

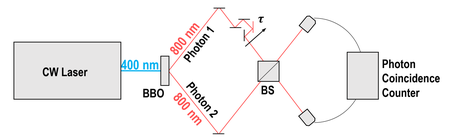


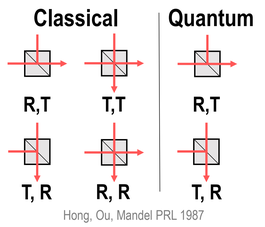


Quantum Optical Spectroscopy

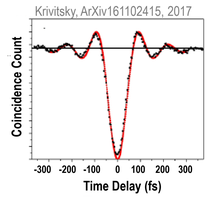
Entangled Photons

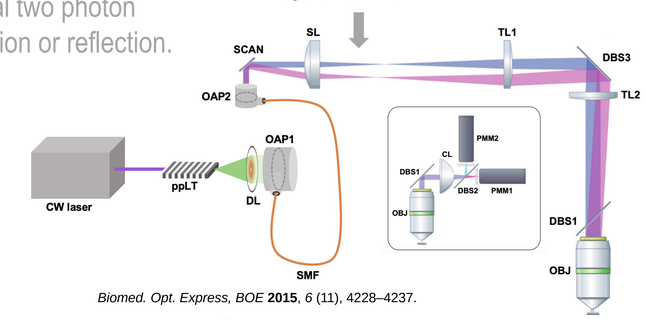
Entangled photons are indistinguishable in terms of light-matter interactions. When interacting with a material, this property means they appear as one photon in absorption and reflection, as opposed to classical two photon absorption or reflection.





Hong, Ou, Mandel PRL 1987

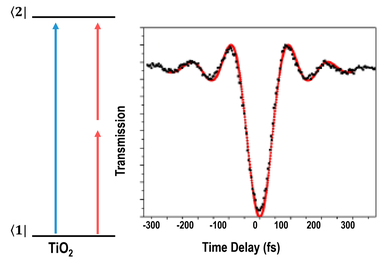




Biomed. Opt. Express, BOE **2015**, *6* (11), 4228–4237.

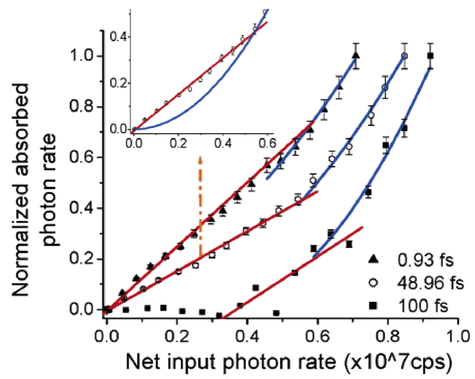
Entangled Photon Spectroscopy

Hong-Ou-Mandel and Light-Matter Interactions



Krivitsky, ArXiv161102415, 2017

Expanding the utility of low flux spectroscopy



Lee & Goodson, JPCLB, 2006

Absorption Cross-section

Classical Two-Photon

$10^{-48} cm^4 s$

One-Photon

$10^{-16} cm^2$

Entangled Two-Photon

$\sim 10^{-17} cm^2$