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Time-Resolved Spectroscopy & Ultrafast Phenomena

S&T Campaign: Materials Research
Photonics

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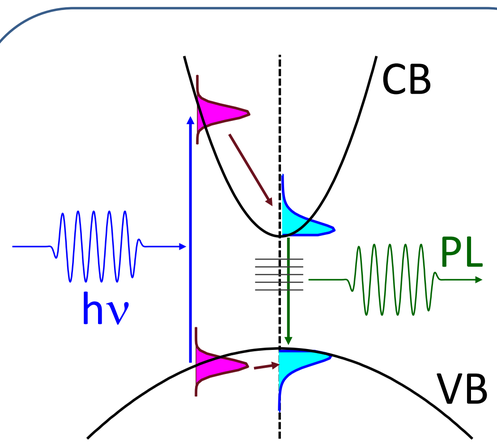
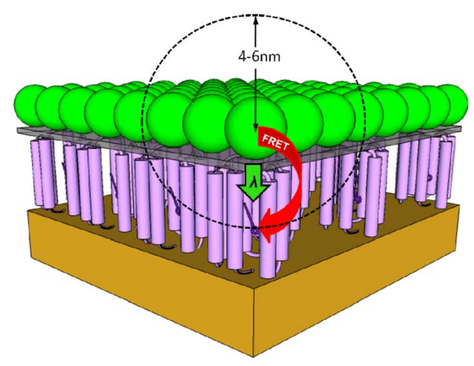
Research Objectives

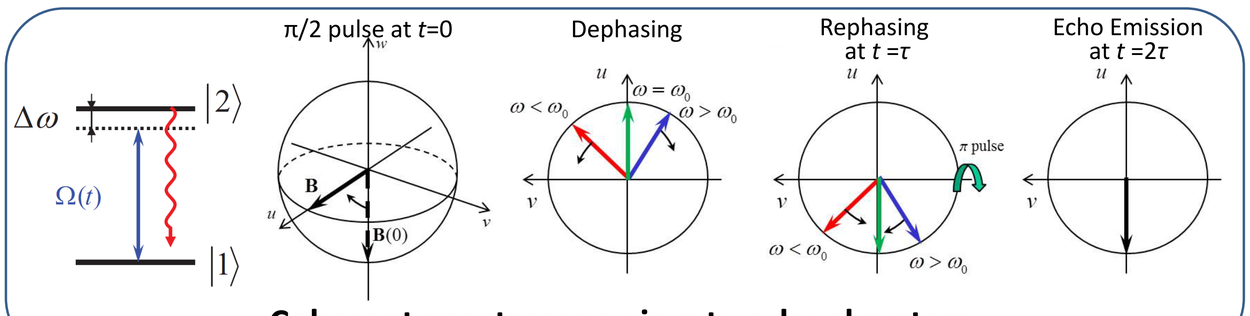
- The study of electron, phonon, and other quasi-particle dynamics in emergent materials and state-of-the-art devices.
- Investigate quantum phenomenon in semiconductor-light interactions using coherence spectroscopy for applications in quantum information.



Dynamics of photo-excited carriers in a semiconductor.



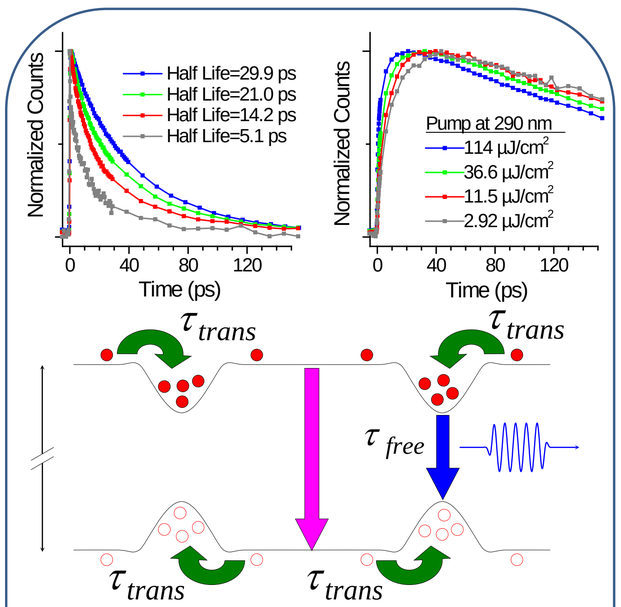
Energy capture and transfer in molecular and quantum dot systems.



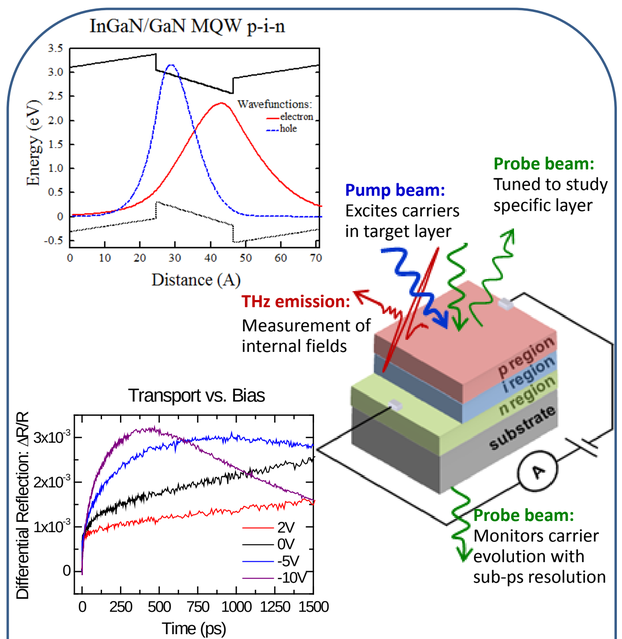
Coherent spectroscopy in a two-level system.

Challenges

- Identifying a combination of sample design and diagnostic techniques to extract information on relevant carrier dynamics/phenomena.
- Developing robust models to connect observations with material/device properties of interest.
- Working in the ultraviolet and far-infrared spectrums.



Carrier capture and emission from localized states.



Carrier transport studies in heterostructure devices.

ARL Facilities and Capabilities Available to Support Collaborative Research

- Three 250-kHz Coherent RegA Ti:Sapphire lasers
  - 100-fs optical pulses at 800 nm with > 6 μJ/pulse.
  - Optical parametric amplifiers (OPA) tunable through the visible and down to 2.4 μm.
  - Doubled OPA gives pulses tunable through the UV.
  - Difference frequency generator (DFG) pulses (2 – 10 μm).
- One 76-MHz Spectra-Physics Inspire OPA
- Broad range of time-resolved detection techniques
  - Time-correlated single photon counting with a multi-channel plate PMT; 25-ps resolution.
  - Ultrafast streak camera with synchronous sweep (3-ps resolution) or triggered sweep drivers.
  - Optical gating by frequency mixing in a non-linear crystal; sub-picosecond time resolution.
  - Various optical delay rails and modulators for differential transmission and reflection, pump-probe, and four wave mixing techniques.
- Optical THz pulse generation and detection for time-domain THz spectroscopy.
- Developing novel Ultrafast Electron Spectroscopy (UES) system with picosecond electron pulse excitations.
- Research Highlights:
  - Investigation of trap states in mid-wavelength infrared type II superlattices using time-resolved photoluminescence.
    Blair C. Connelly *et al*, J. Electron. Mat. **42**, 3203, 2014.
  - Time-resolved electroabsorption measurement of carrier velocity in inverted polarity $In_{1-x}Ga_xN/GaN$ heterostructures due to internal electric fields.
    Blair C. Connelly *et al*, Phys. Status Solidi C **11**, 682, 2013.
  - Theoretical and experimental study of dynamics of photoexcited carriers in GaN.
    Sara Shishehchi *et al*, J. Appl. Phys. **114**, 233106, 2013.
  - Terahertz studies of carrier localization in spontaneously forming polar lateral heterostructures.
    Grace D. Metcalfe *et al*, Phys. Status Solidi RRL **7**, 993, 2013.
  - Förster resonance energy transfer between core/shell quantum dots and bacteriorhodopsin.
    Mark H. Griep *et al*, Mol. Biology Int. **2012,** 910707, 2012.
- Unique ARL expertise in Ultraviolet , Mid- and Long-Wavelength IR, and time-resolved THz spectroscopy.

Complementary Expertise/ Facilities/ Capabilities Sought in Collaboration

- Innovative materials and device designs that provide for improved and interesting:
  - UV optoelectronics (lasers diodes, LEDs, and detectors)
  - Mid- and Long-wavelength IR detectors
  - Coherence effects in wide band gap semiconductors
  - Metamaterials and plasmonics
  - Van der Waals heterostructures and topological insulators
- Modeling of ultrafast carrier dynamics/phenomena.

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