# Time-Resolved Spectroscopy & Ultrafast Phenomena

**S&T Campaign: Materials Research**
***Photonics***

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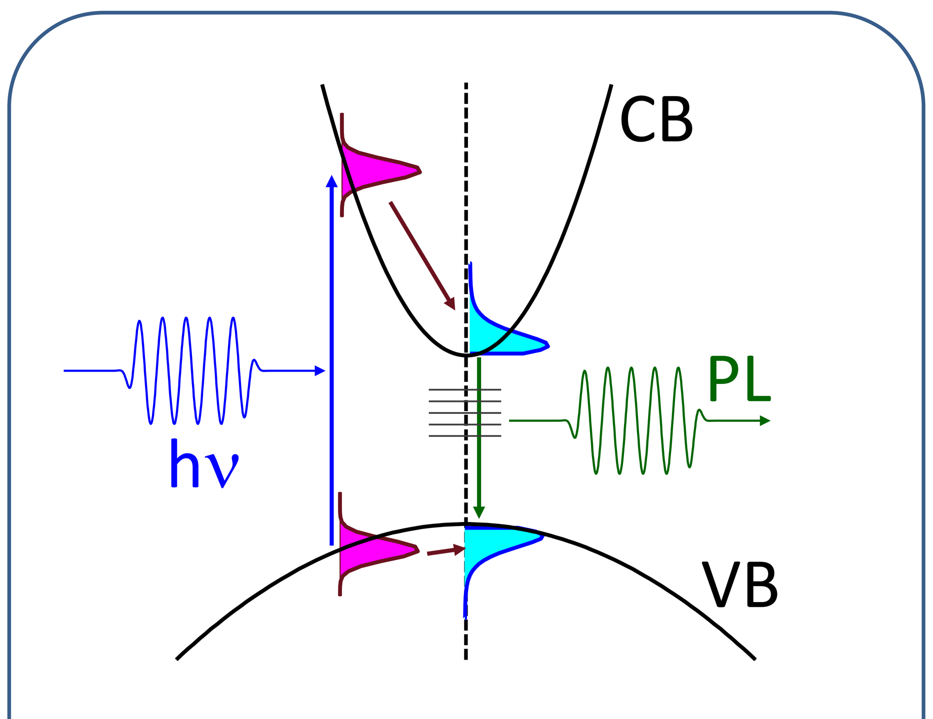
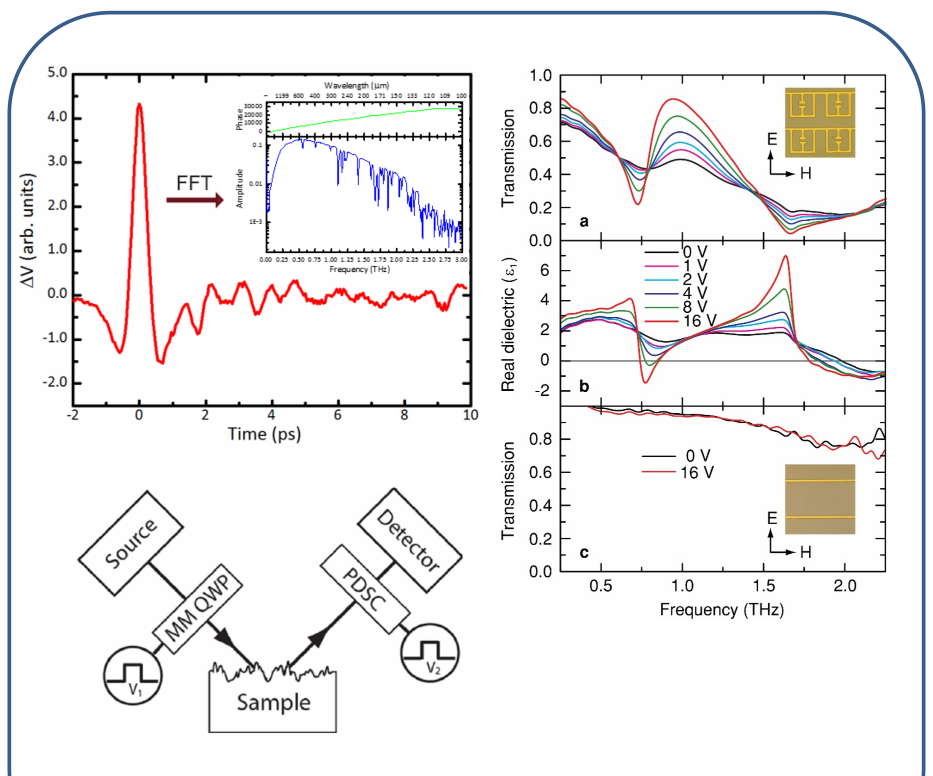
## Research Objective

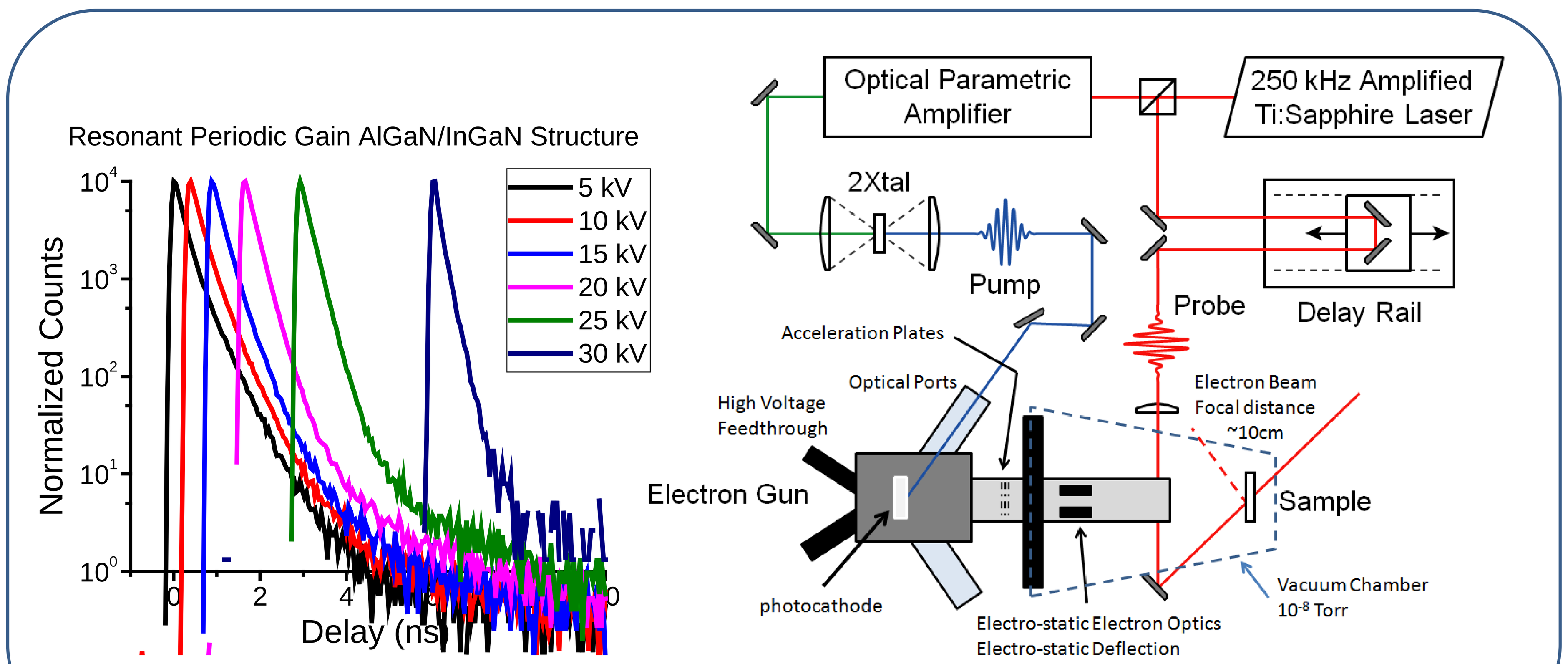
- **The study of electron, phonon, and other quasi-particle dynamics in emergent materials and state-of-the-art devices**
- **Investigate quantum phenomenon in semiconductor-light interactions using coherence spectroscopy for applications in quantum information**



**Dynamics of photo-excited carriers in a semiconductor**



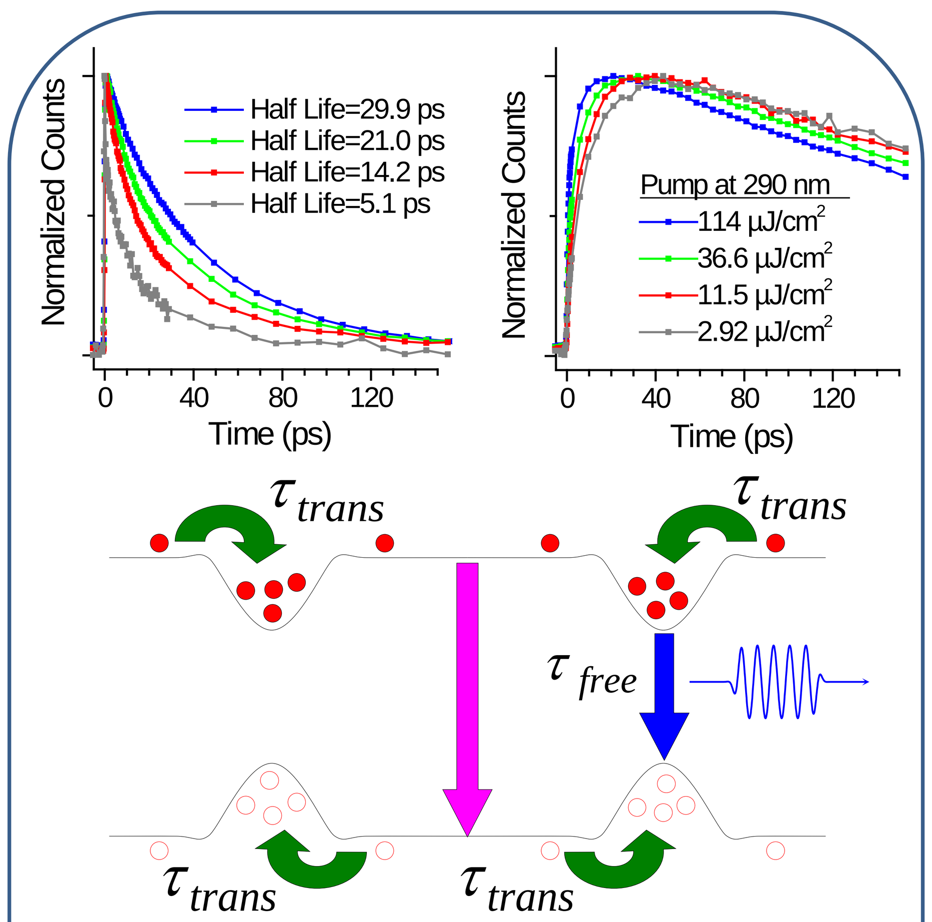
**Time domain THz Spectroscopy**



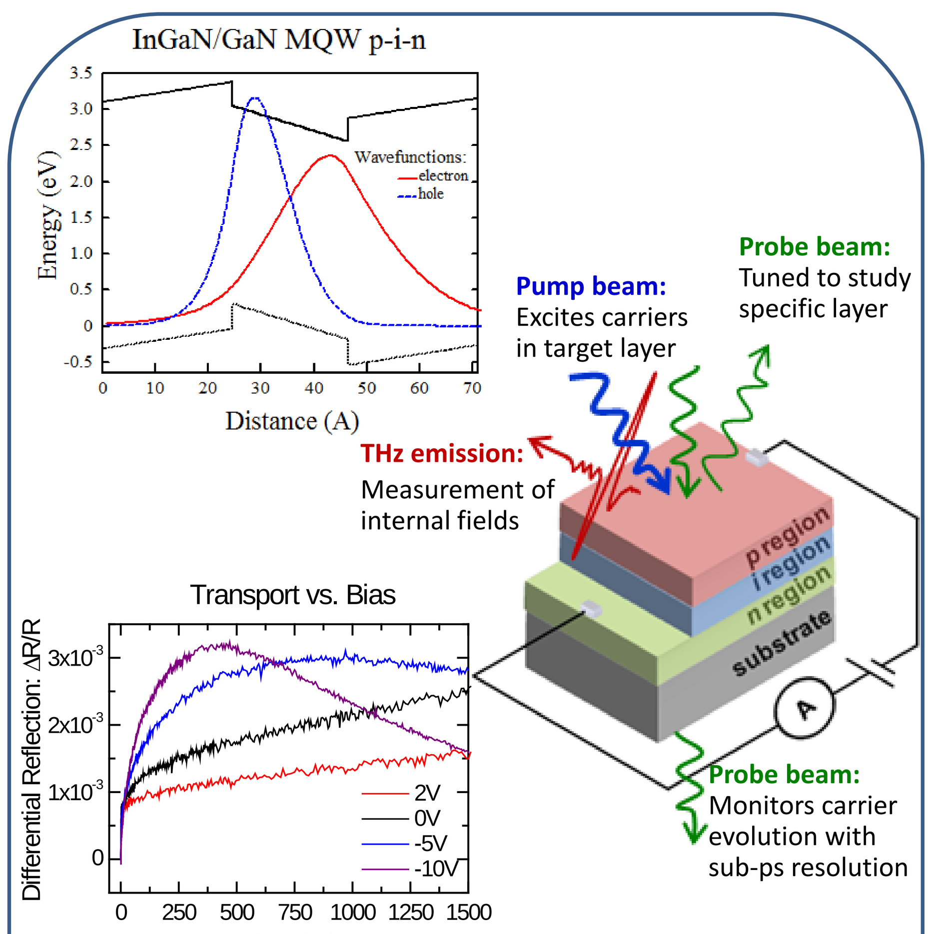
**Ultrafast electron spectroscopy**

## 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**
    - Gregory A. Garrett 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.
  - **Pseudomorphically Grown Ultraviolet C Photopumped Lasers on Bulk AlN Substrates**
    - Gregory A. Garrett et al, Appl. Phys. Exp., 4, 092101, 2011.
  - **Crystal-Field Spilt Levels of $Nd^{3+}$ Ions in GaN Measured by Luminescence Spectroscopy**
    - Grace D. Metcalfe et al, J. Appl. Phys., 105, 053101, 2009.
  - **Unique ARL expertise in Ultraviolet, Mid- and Long-Wavelength IR, and time-resolved THz spectroscopy**

## Complementary Expertise / Facilities / Capabilities Sought in Collaboration

- **Modeling of ultrafast carrier dynamics/phenomena**
- **Innovative materials and device designs**
  - **UV optoelectronics (laser diodes, LEDs, detectors)**
  - **Mid- and long-wavelength IR detectors**
  - **Coherence effects in wide bandgap semiconductors**
  - **Metamaterials and plasmonics**
  - **Van der Waals heterostructures and topological insulators**