High-temperature, Large Format Focal Plane Arrays For Emerging Infrared Sensing Applications

Sandia National Laboratories

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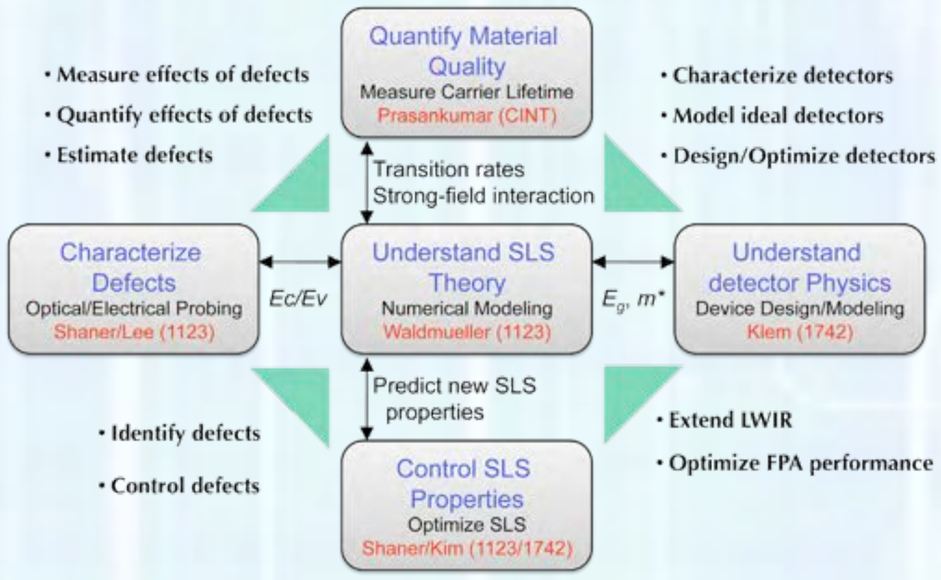
Problem

Project Overview: the Science



Approach

Understand SLS Theory

Why?

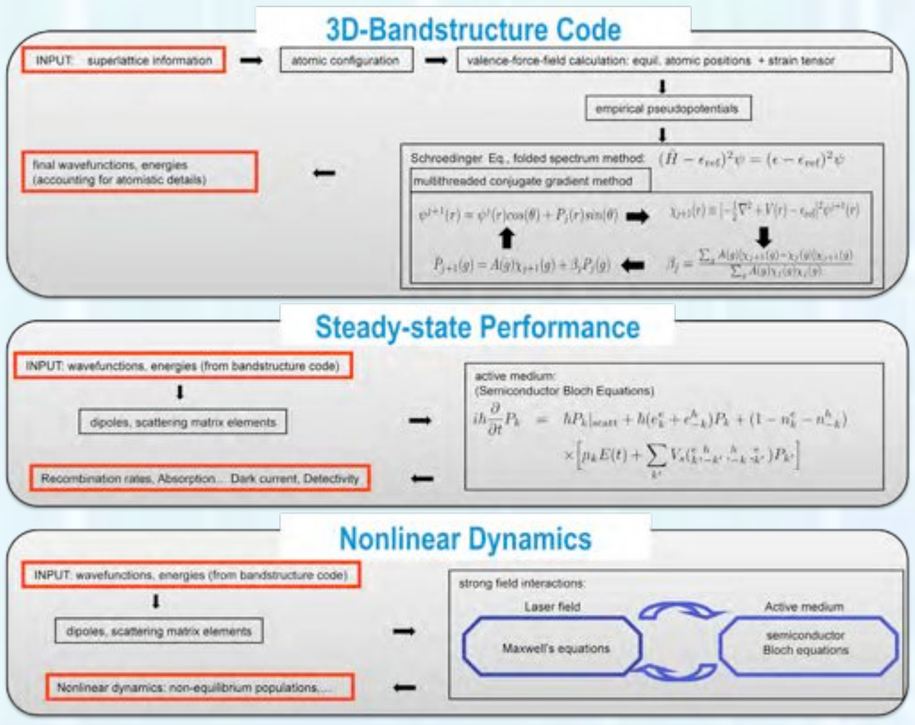
- **Predict Energy Levels: effective E_g, E_c-E_v offsets, heterostructures (static)**
- **Study non-ideal interfaces, atomistic defects (empirical pseudopotential method)**
- **Parametric Fitting: Aid nBn device design and modeling**
- **Quantify absorption rates, carrier lifetime (dynamic)**

Methodology:

- **Empirical pseudopotential method (EPM)**
- **Semiconductor Bloch equations**
- **Maxwell's equations**

Bandstructure + steady-state performance + nonlinear dynamics

allows simulation of steady-state and dynamical superlattice detector characteristics



Approach (cont.)

Carrier Lifetime Measurements

Why?

- **Carrier lifetimes (τ) represent characteristic generation mechanisms ⇒ I_{dark}**
- **Provides device-independent material quality assessment**
- **Reconciling modeled/measured τ permits estimation of defect density/type.**

Methodology: THz pump-probe

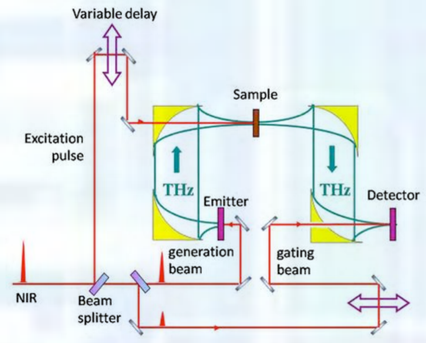
- **Varying pump energy: selective pumping of GaSb, InAs, and/or SLS**
- **THz probing: directly translates to time-dependent carrier density**
- **Currently limited to 3 ns, working on to extend to 1 μs**

	Sample	Periods	InAs	GaSb	Cladding	Variation
1st Set	G252		1000 nm		none	
	G283		50A		AlAsSb	InAs surrounded by AlAsSb
	G284				AlAsSb	like G283, just cladding
	G288	10 pairs	8 ML	8 ML	AlGaSb	baseline SLS
2nd Set			50 A		AlGaSb	different cladding
				50 A	AlGaSb	
		10 pairs	8 ML	80 ML	AlGaSb	exaggerate effects of GaSb
		10 pairs	8 ML	8 ML	AlGaSb	add As in GaSb
		10 pairs	8 ML	8ML	AlGaSb	GaInSb (redshift)

All samples have sacrificial InAsSb etch stop layers.

Results

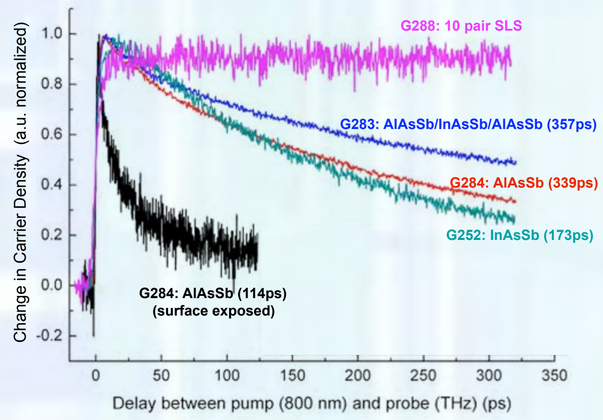
800nm ~50fs Pump – THz Probe



Experimental setup for ultrafast wavelength-tunable pump-probe spectroscopy

- **Laser source is a Coherent RegA ultrafast amplifier system producing ~50 fs pulses at 800 nm with ~10 μJ energy/pulse and 100 kHz repetition rate**
- **Nonlinear ZnTe crystals are used for generation and detection of THz radiation**
- **The "Gate Pulse" is used for the coherent detection of THz pulses via electro-optic sampling technique**
- **Accurate measurements of low-level THz signal amplitude change is accomplished using a polarization sensitive detection scheme involving lamda/4 plate, Wollaston prism and balanced photo-detectors**

Room-T Carrier Lifetime Measurement

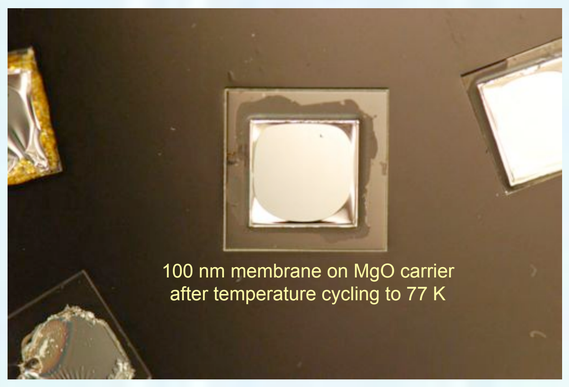


Significance

Sample Fabrication

Advances in Fabrication

- **<100 nm membranes can now be suspended on THz transparent holder.**
- **Stable after temperature cycle to 77 K**
- **Oxidation mechanisms of AlAsSb under investigation.**



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