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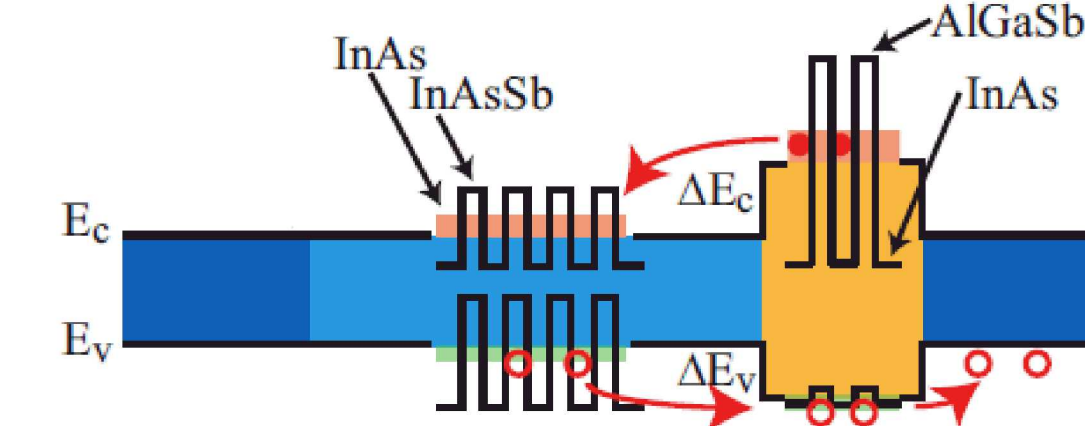
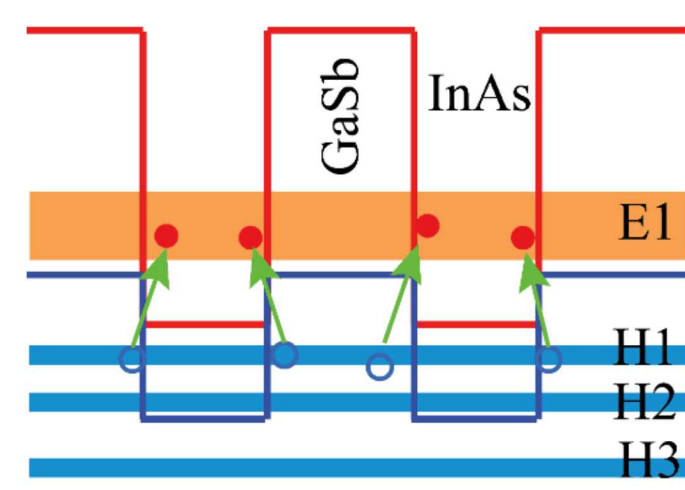
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## I. Introduction

**Strained layer superlattices:** A structure of alternating two different materials with quantum mechanically small thicknesses

- Higher operating temperatures
- Suppression of Auger recombination
- Easy to tune the effective band gap

Band alignment of InAs/GaSb

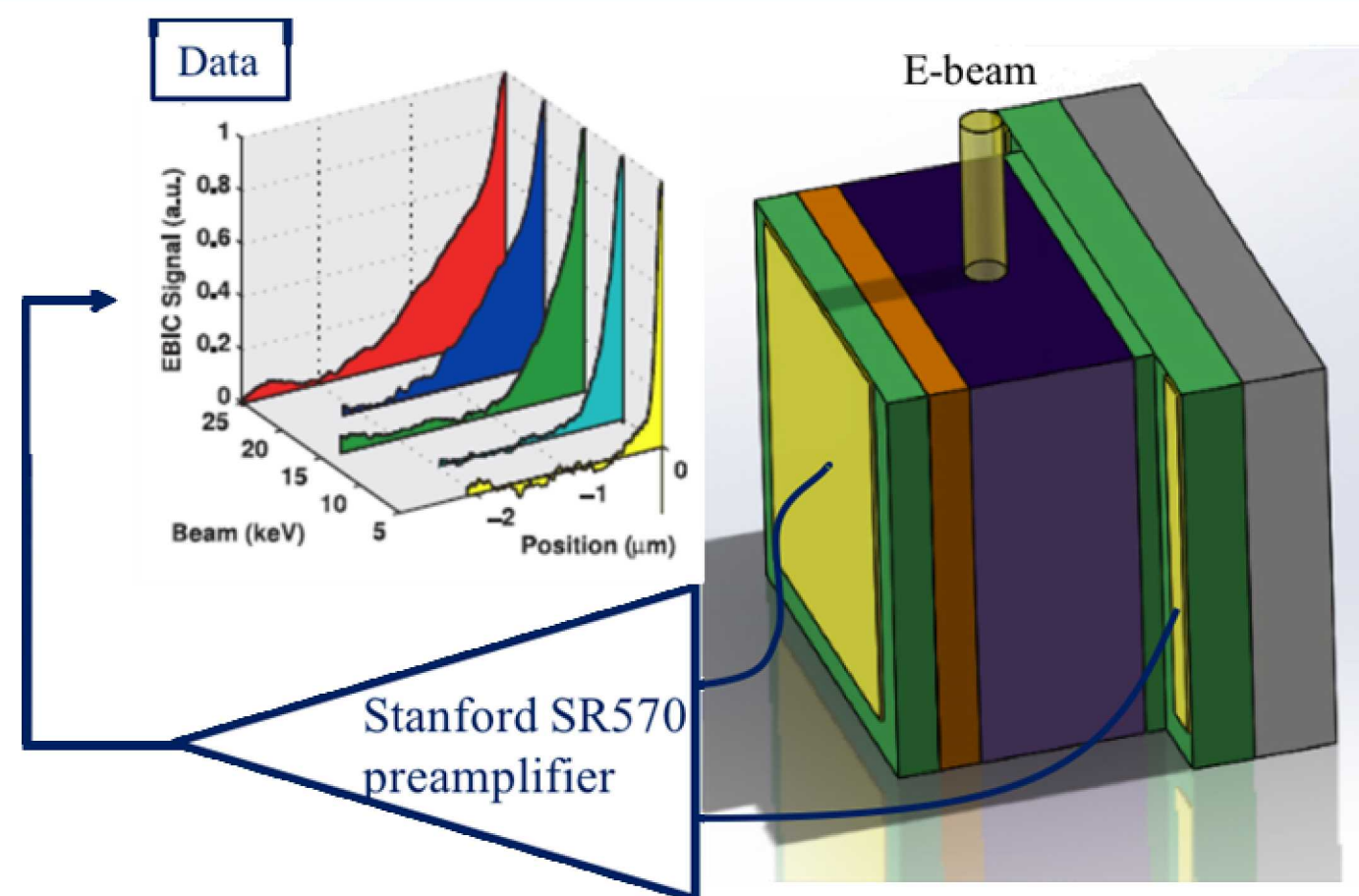


Band alignment of the nBn structured strained layer superlattice

**nBn structured detectors:**

- Barrier blocks majority carrier flow of the absorber
- Dark current reduction, compared to pin structure

## II. Material Characterization



**Electron Beam Induced Current (EBIC):**

- Generates electron hole pairs using electron beam of SEM
- Collects amplified current signal
- Fits to EBIC model to extract parameters ( $L$  and  $S/D$ )

**EBIC Modeling:**

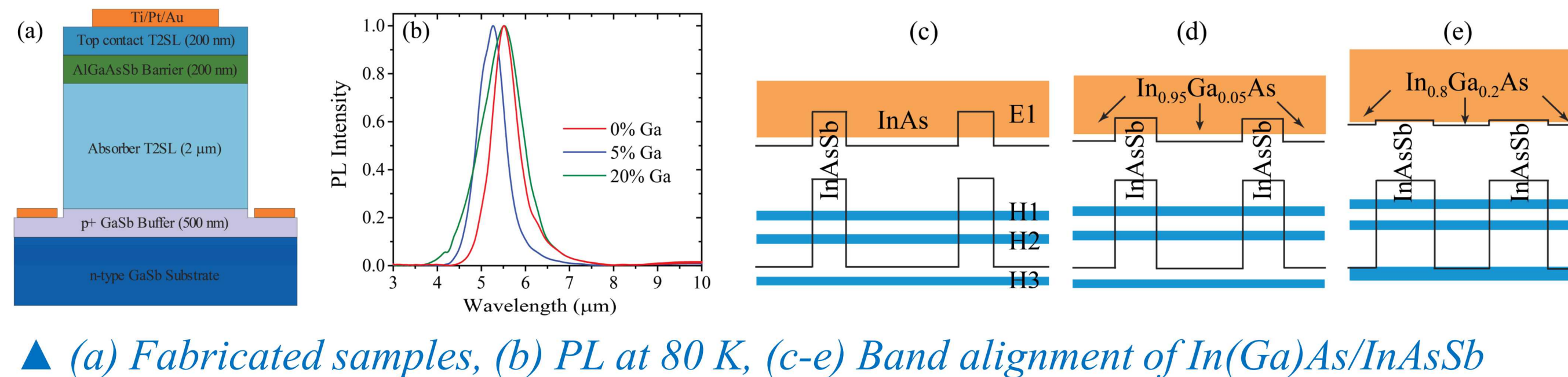
- Collection Efficiency,  $\eta(x) = \int_{-\infty}^{\infty} d\tilde{x} \int_0^{\infty} h(\tilde{x}-x, \tilde{z}) \varphi(\tilde{x}, \tilde{z}) d\tilde{z}$
- Carrier Generation Volume,  $h(\tilde{x}-x, \tilde{z}) \rightarrow$  Monte Carlo Simulation
- Probability of Collection,  $\varphi(\tilde{x}, \tilde{z}) \rightarrow$  diffusion equation

Illustration of the Electron Beam Induced Current measurement setup

## III. Experimental Results

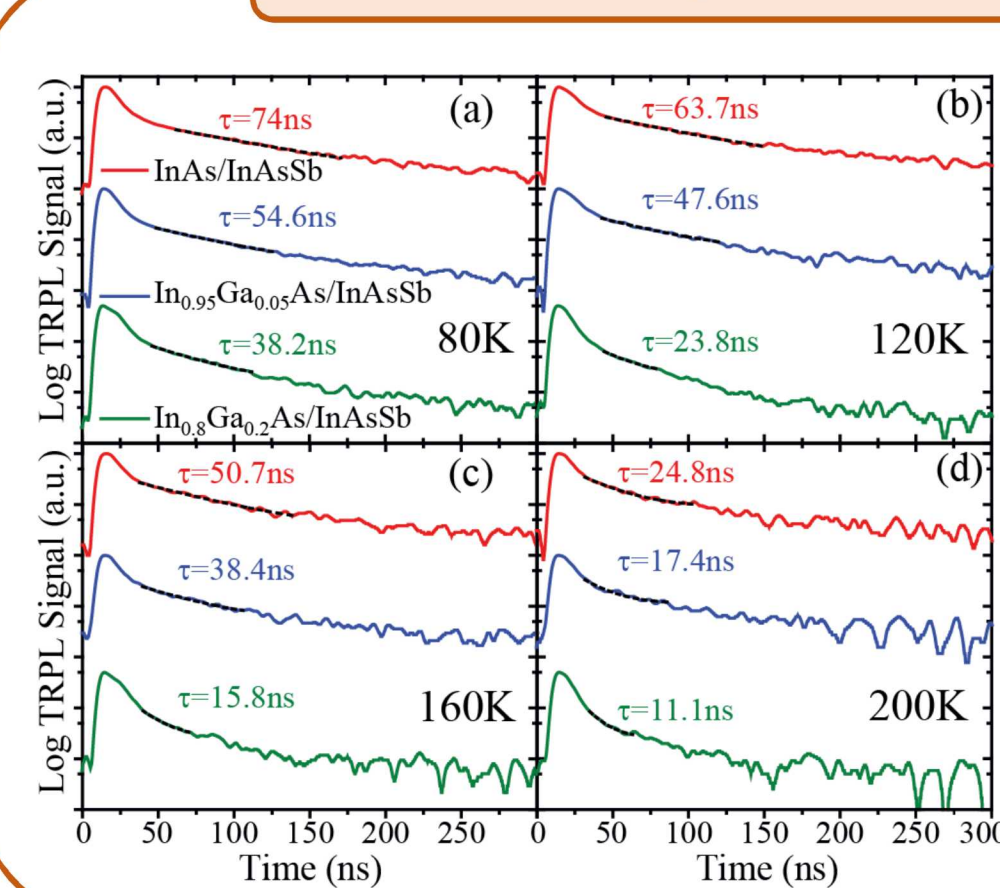
**Sample Description:**

- Three different samples were characterized to study the effect of Ga content in In(Ga)As/InAsSb
- The vertical hole mobility was expected to be greater as Ga content increases

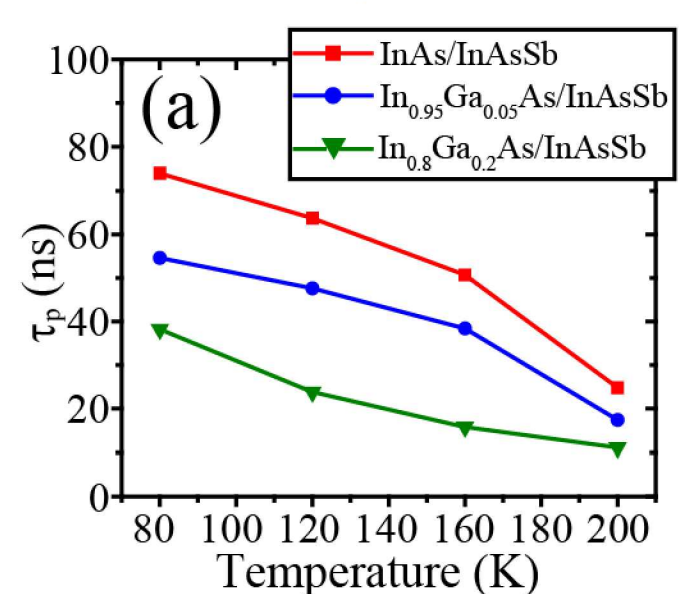


(a) Fabricated samples, (b) PL at 80 K, (c-e) Band alignment of In(Ga)As/InAsSb

**Time-resolved photoluminescence (TRPL)**



Samples are pumped with a  $\sim 1$ ns pulsed laser at  $\lambda=1064$ nm, and the light emitted from the samples is collected with a parabolic mirror and focused onto the high-speed MCT detectors with Ge lens.

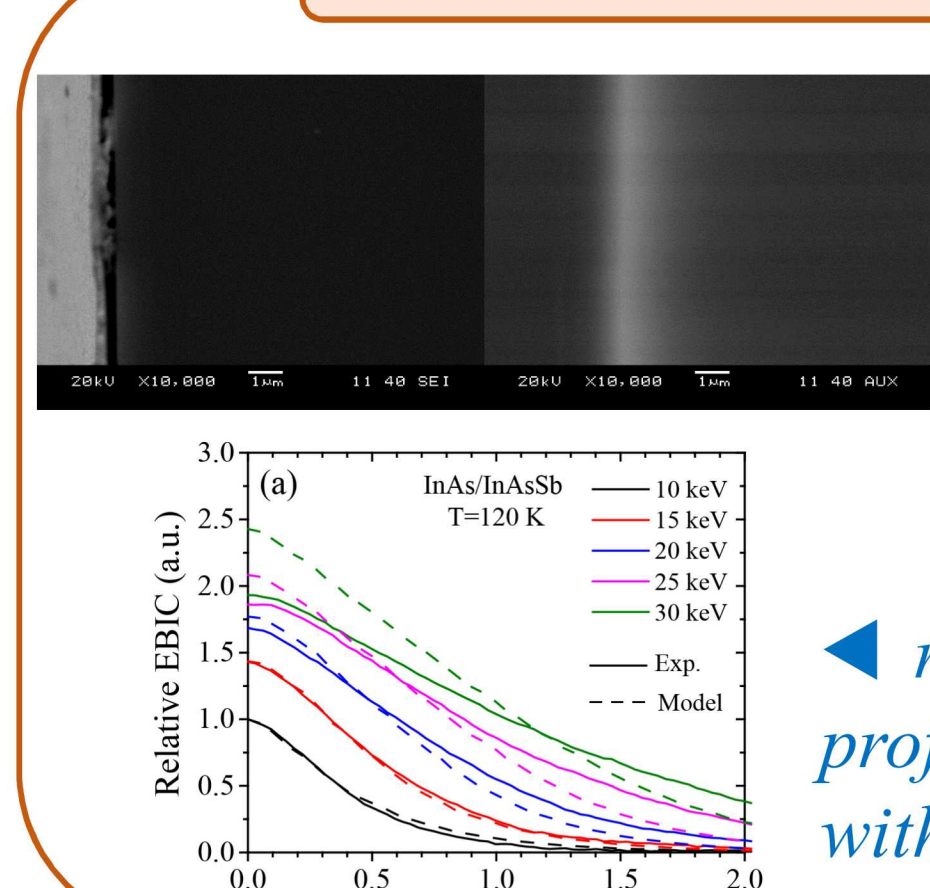


minority carrier lifetime (TRPL)

hole diffusion length (EBIC)

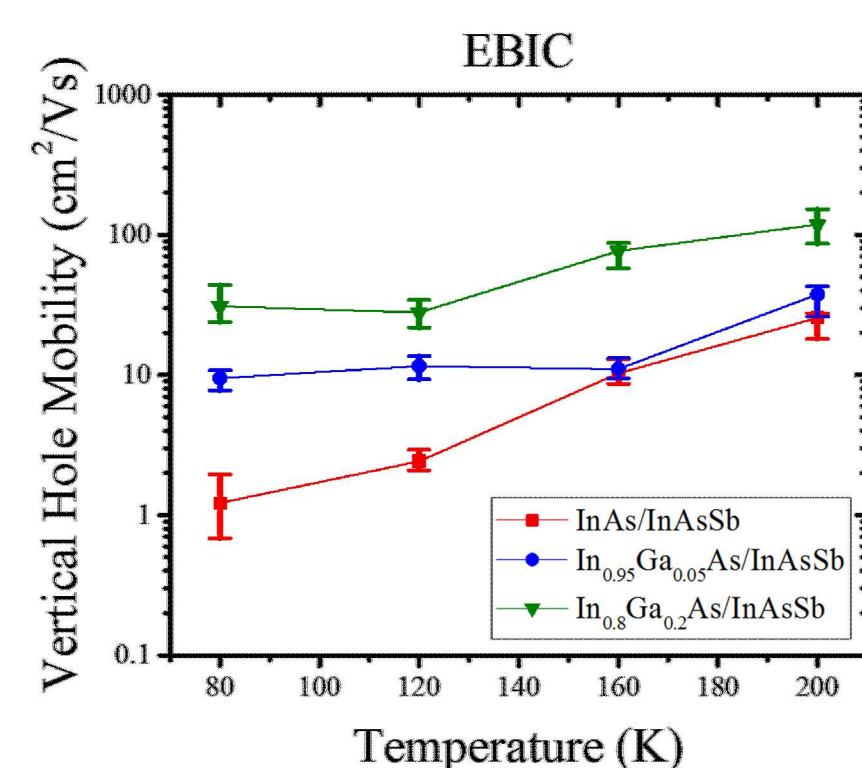
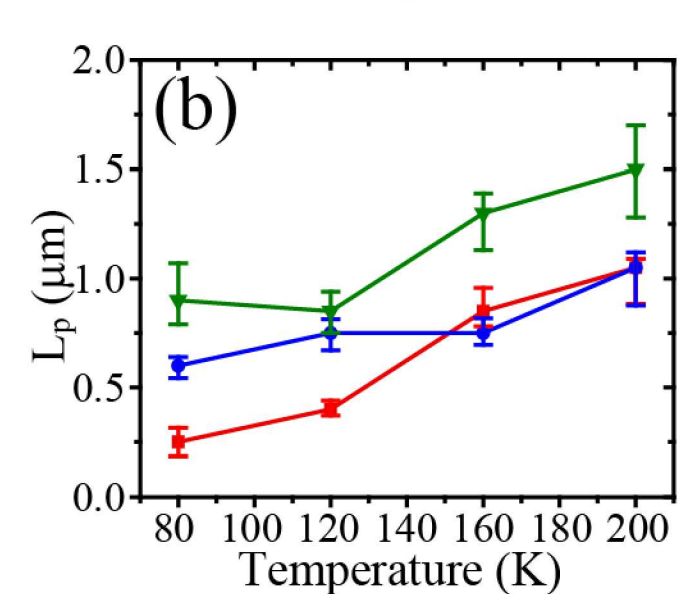
$$D_h = L_h^2 / \tau_p \quad \& \quad \mu_h = qD_h / kT$$

**Electron beam induced current (EBIC)**



Scanning Electron Microscopy (SEM) image and Electron Beam Induced Current (EBIC) image, respectively

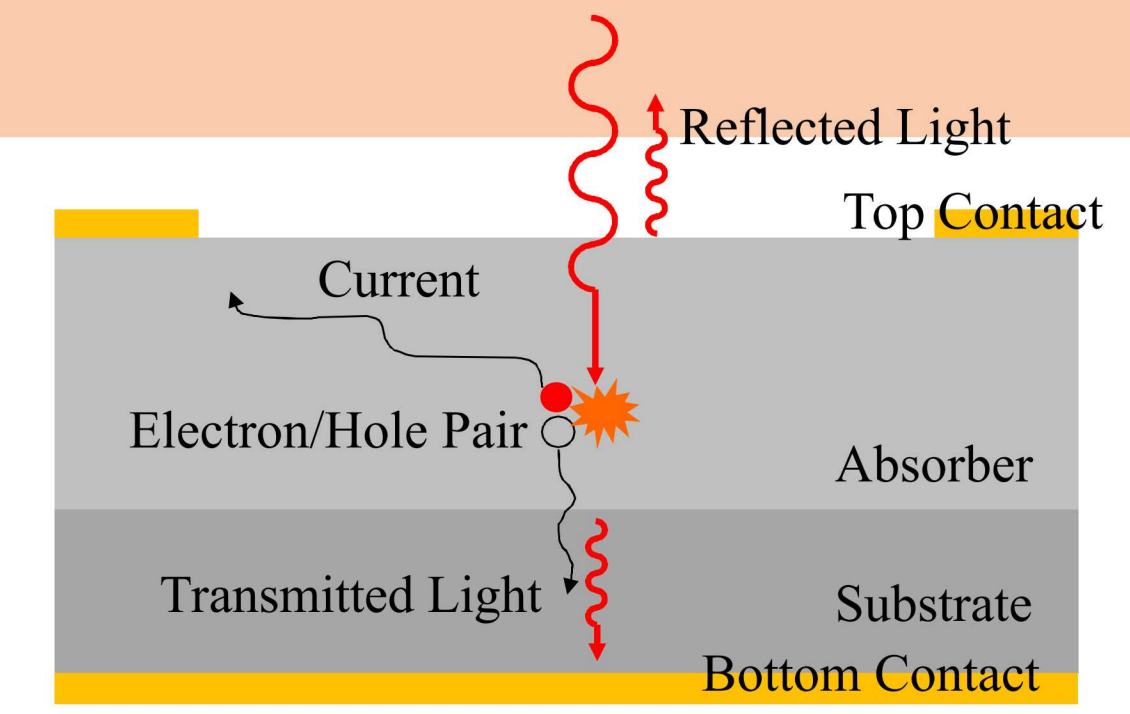
relatively normalized EBIC profiles as a function of position with various beam energies



## IV. Problem Statement

**Strained Layer Superlattice – Infrared Detector Material:**

- The absorption of most mid-IR and long-IR absorbing materials is weak
- Possible solution #1: Thicker absorber
  - Short diffusion length ( $< 2 \mu\text{m}$ ) degrades the collection efficiency
- Possible solution #2: Metal as a mirror
  - Weak electric field; Requires complex fabrication process



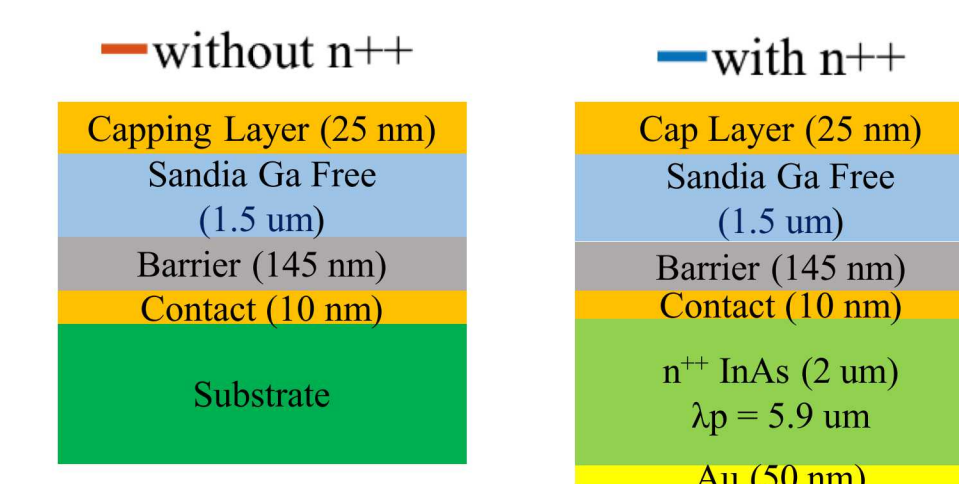
## V. Proposed Novel Architectures

**Utilizing highly doped semiconductor:**

- Highly doped semiconductor works as a ground plane of the optical cavity

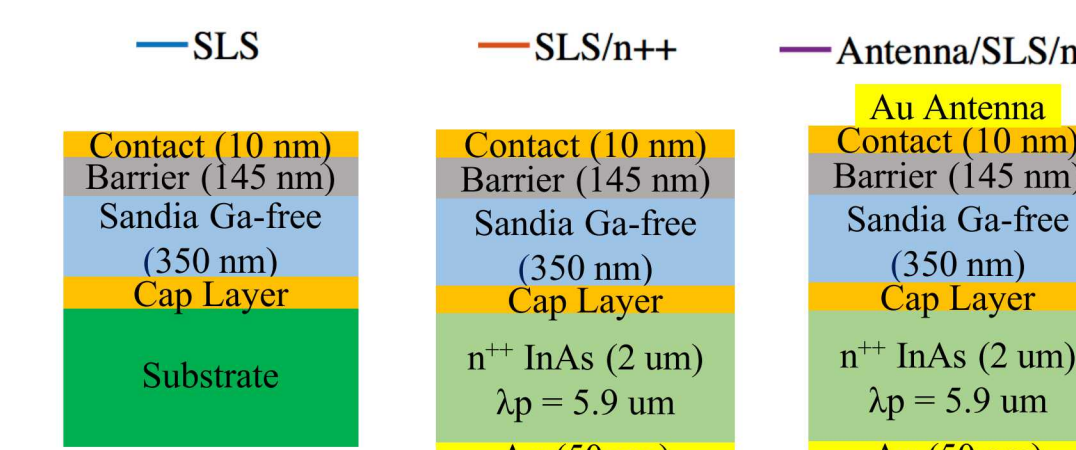
**Thin Detector:**

- 1.5  $\mu\text{m}$  thick SLS absorber
- With a highly doped ground plane, SLS absorption increases from  $\sim 10\%$  to  $\sim 50\%$

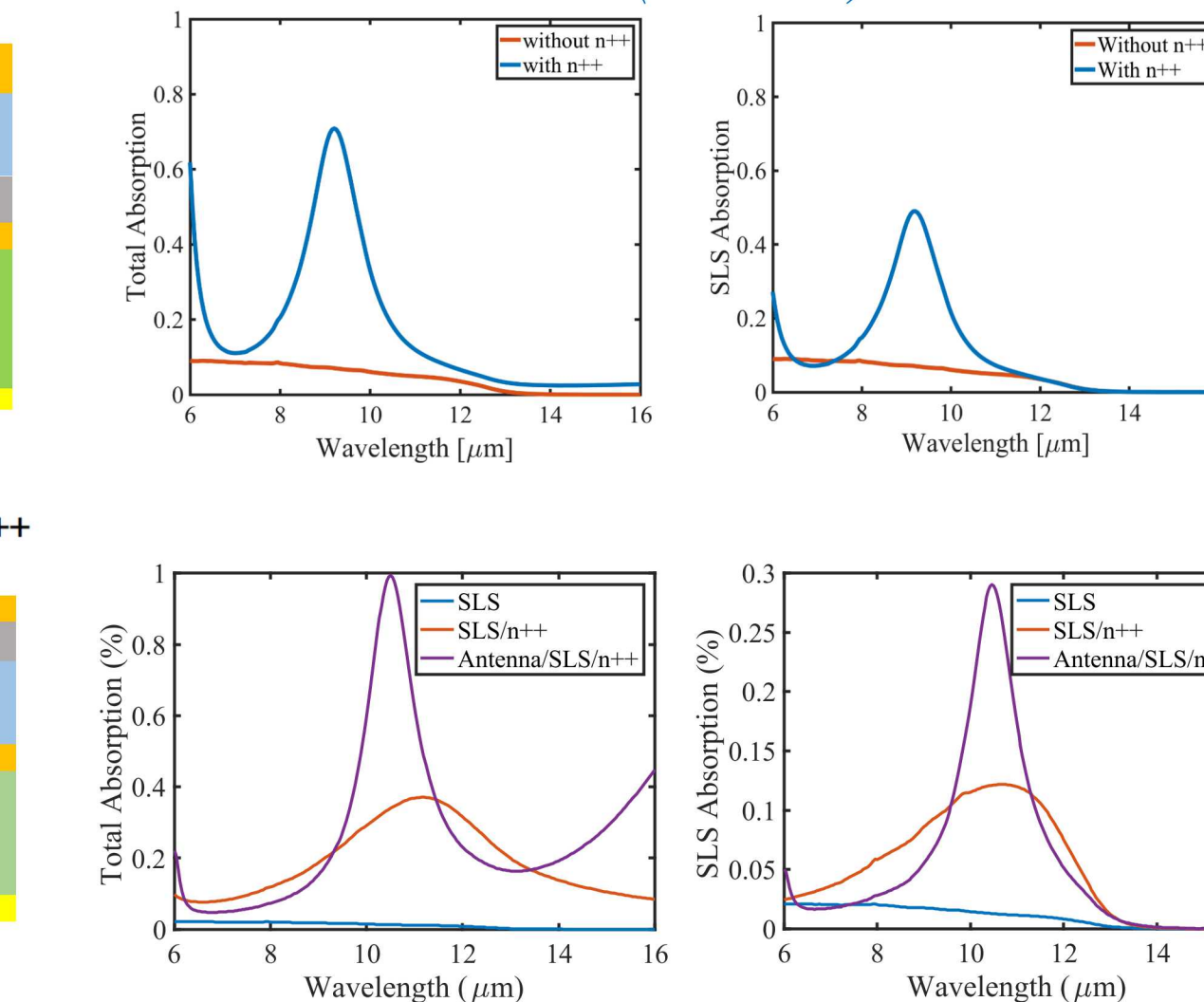


**Ultra-Thin Detector:**

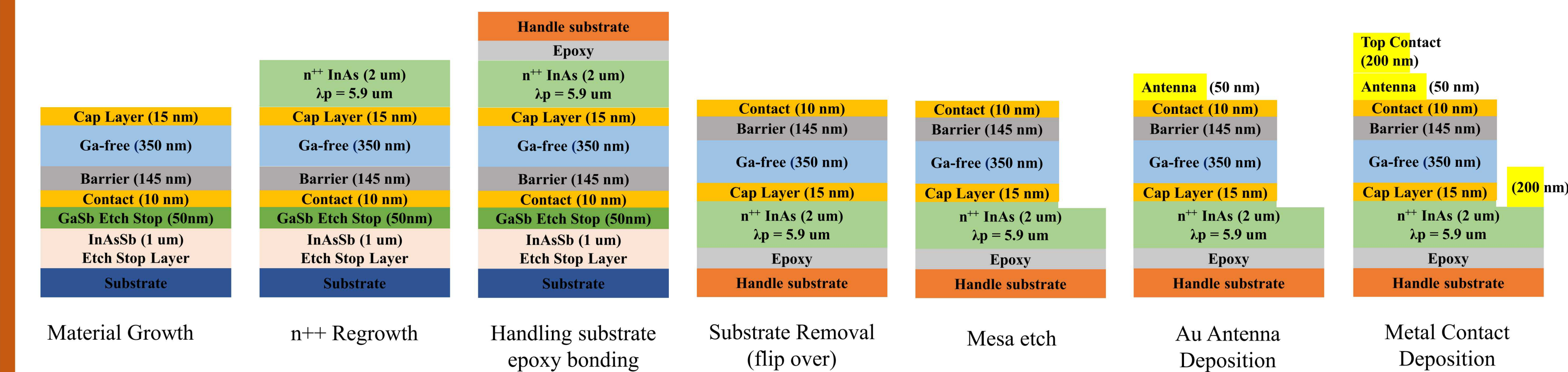
- 350 nm thick SLS absorber
- With a highly doped ground plane and Au Antenna, SLS absorption increases from  $\sim 2\%$  to  $\sim 29\%$



Rigorous Coupled Wave Analysis (RCWA) simulations for thin detectors (top) and for ultra-thin detectors (bottom)



## VI. Fabrication Flow for Ultra-Thin Detector



## VII. Summary / Future Work

- Strained-Layer Superlattices (SLSS) have theoretically better performance than commercially available infrared detectors, such as QWIPs, MCT, etc.
- By using EBIC technique, the quantitative material characterization is done on the fabricated device to extract diffusion length ( $L$ ) and surface recombination velocity to diffusivity ratio ( $S/D$ )
- The thicker absorber can absorb more light, but the short diffusion length of SLS degrades the collection efficiency. Utilizing highly doped semiconductor materials, SLS detector can have enhanced absorption with a thin absorber. Because of the limited growth capabilities, the highly doped semiconductor was re-grown on the SLS detector, which requires substrate removal for the current work.

## VIII. References

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