LWIR DETECTOR RESEARCH IN InAsSb/InAs

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The InAsSb/InSb strained-layer system forms a type-II superlattice in the Sb-rich region of the phase diagram. The band gap of InAsSb/InSb strained-layer superlattices grown on lattice-matched buffers can be varied continuously to produce semiconducting systems with band gaps ranging from that of InSb (0.23 eV with an absorption edge at 5.5 μm at 77 K) to 0. The semiconductor to semimetal transition occurs at As concentrations of approximately 30 %, with the precise value dependent upon the strain and quantum well dimensions. At higher As content, the system is a semimetal. We have fabricated photovoltaic detectors with high D* at 77 K at wavelengths beyond 10 μm, and both photovoltaic and photoconductive detectors have been demonstrated with response to 15 μm. The photoconductive detectors exhibit gain of up to 100. This talk will discuss details of the materials growth, studies of the band structure and properties, device processing and the detector performance observed to date in these systems.

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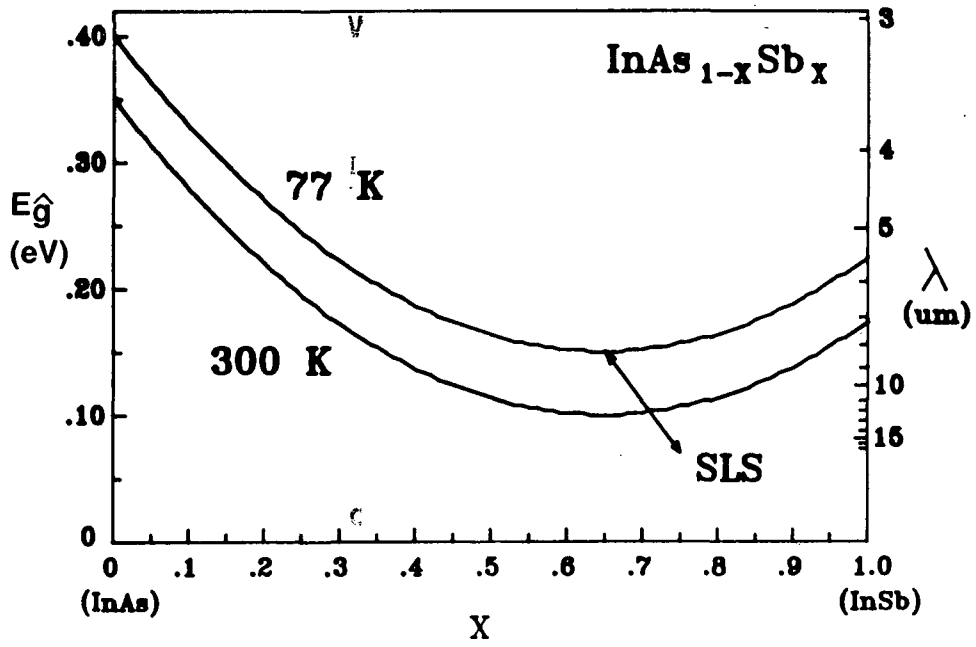
psp04.01.90

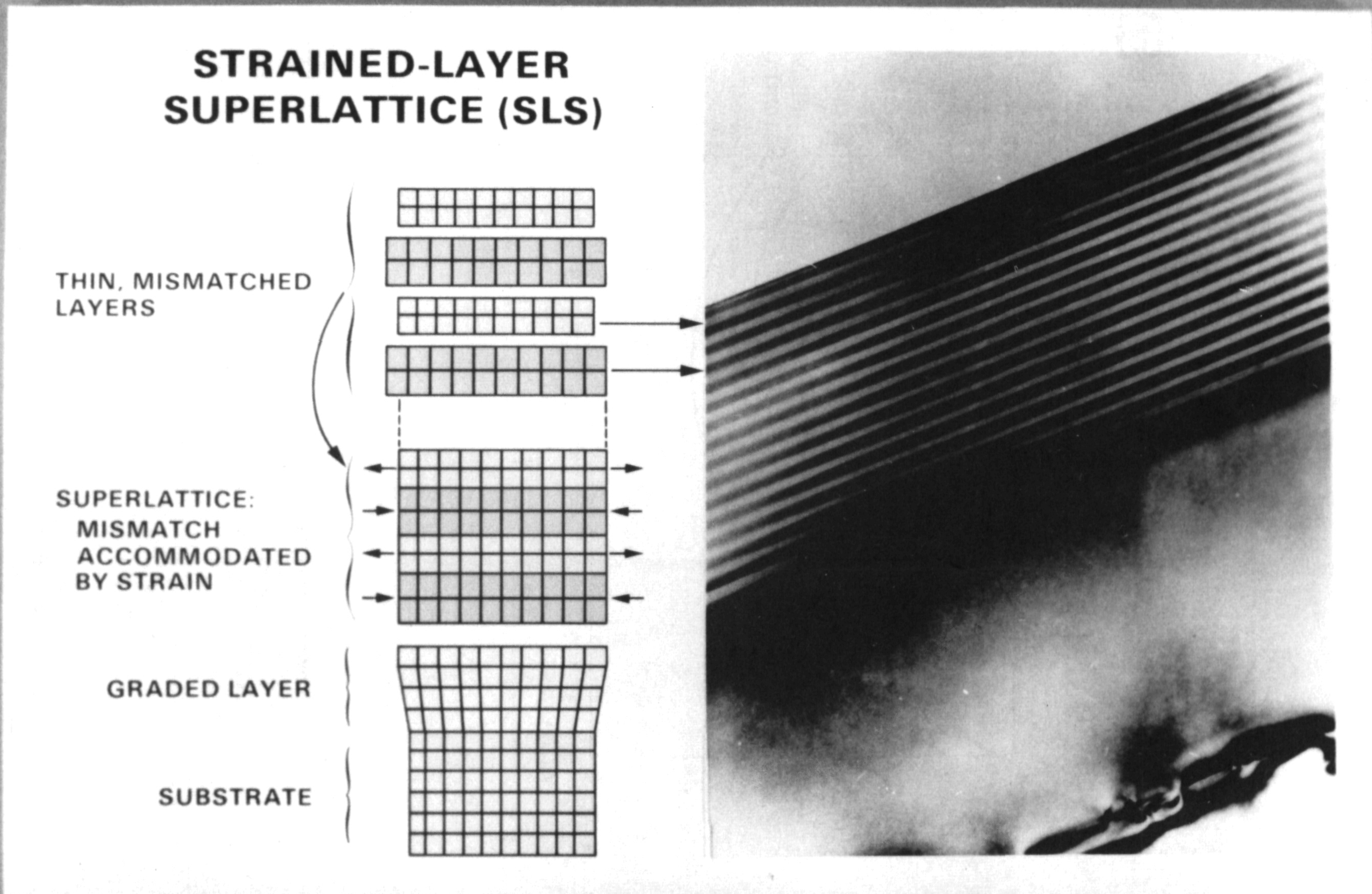
OUTLINE

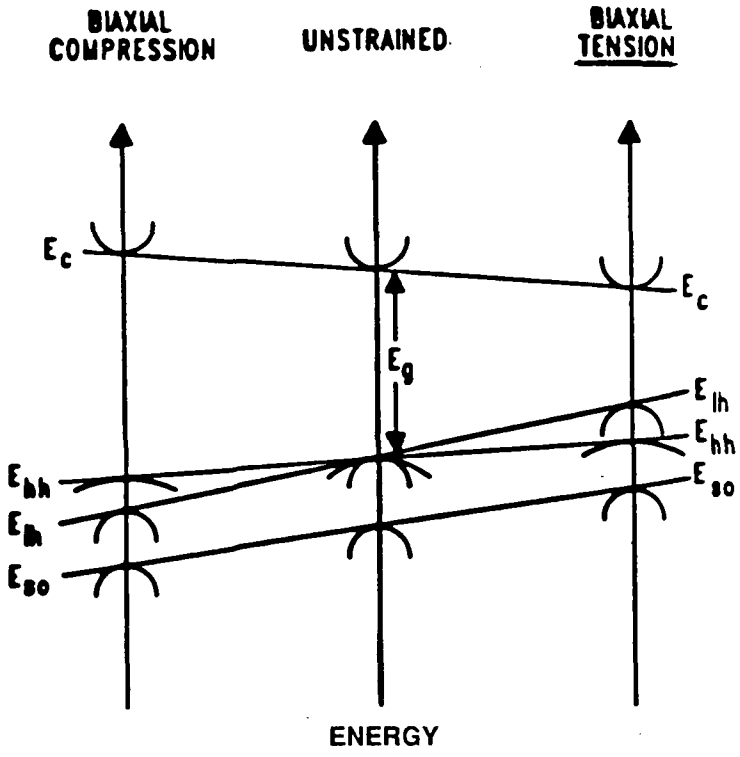
- Summary of InAsSb SLS Properties
  - Band structure
  - Optical properties
- Photoconductive Detectors
  - High gain type II superlattices
- Photovoltaic Detectors
  - Electrical characteristics
  - Detector response
- Extension to wavelengths beyond 10 μm
- Process Monitors and control
  - REMS for on-line growth control
  - PL for monitoring material quality
  - Processing issues
- Summary

psp04.11.90

ENERGY GAP IN THE InAsSb ALLOY SYSTEM

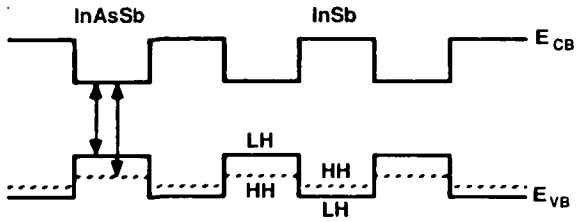






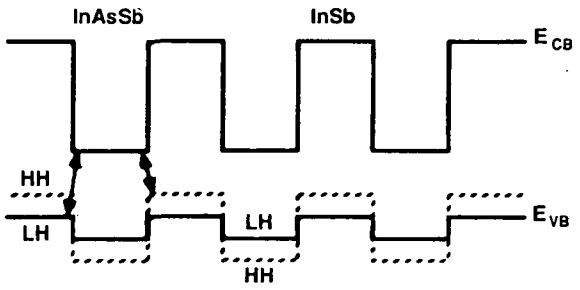
TYPE I OFFSET:

(Spatially "direct", low energy transitions)

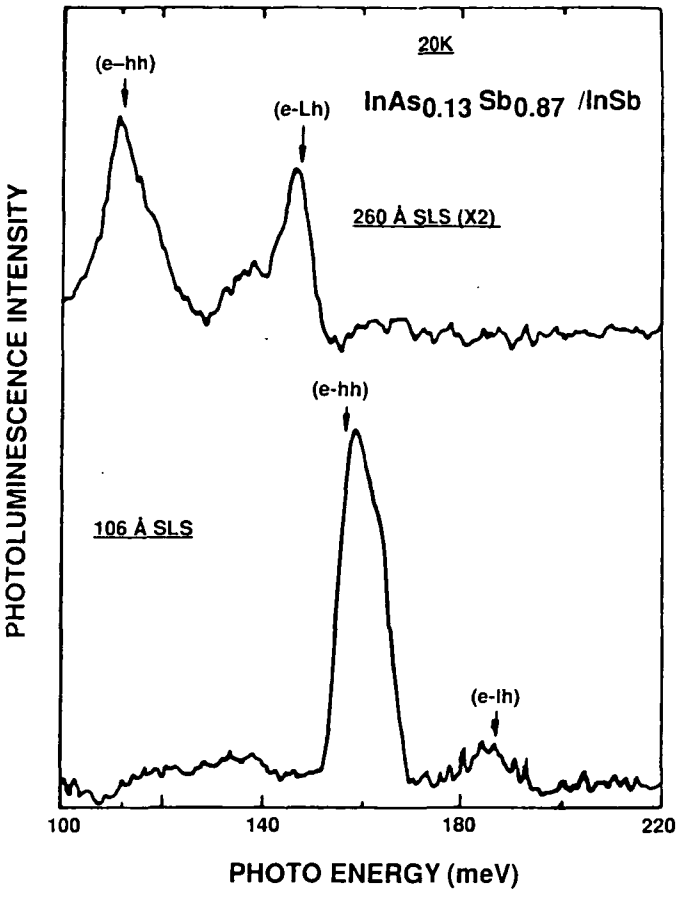


TYPE II OFFSET:

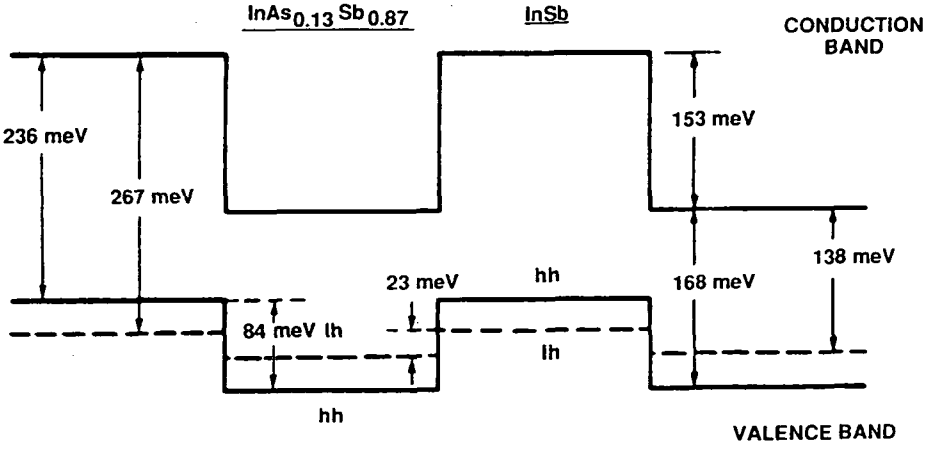
(Lower energy, spatially "indirect" transitions)



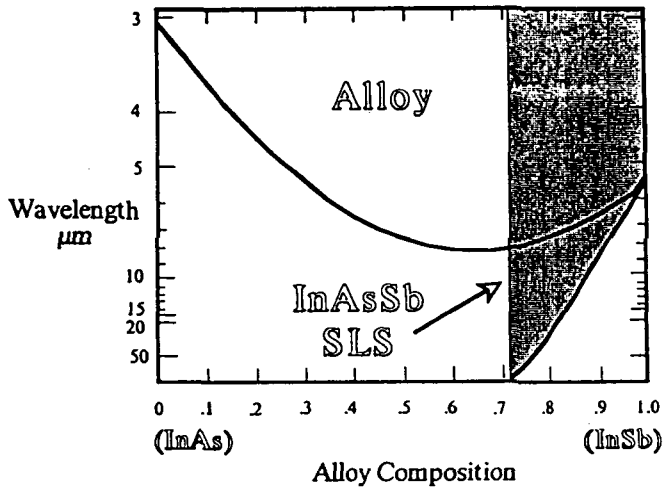
Infrared Photoluminescence (SLS)



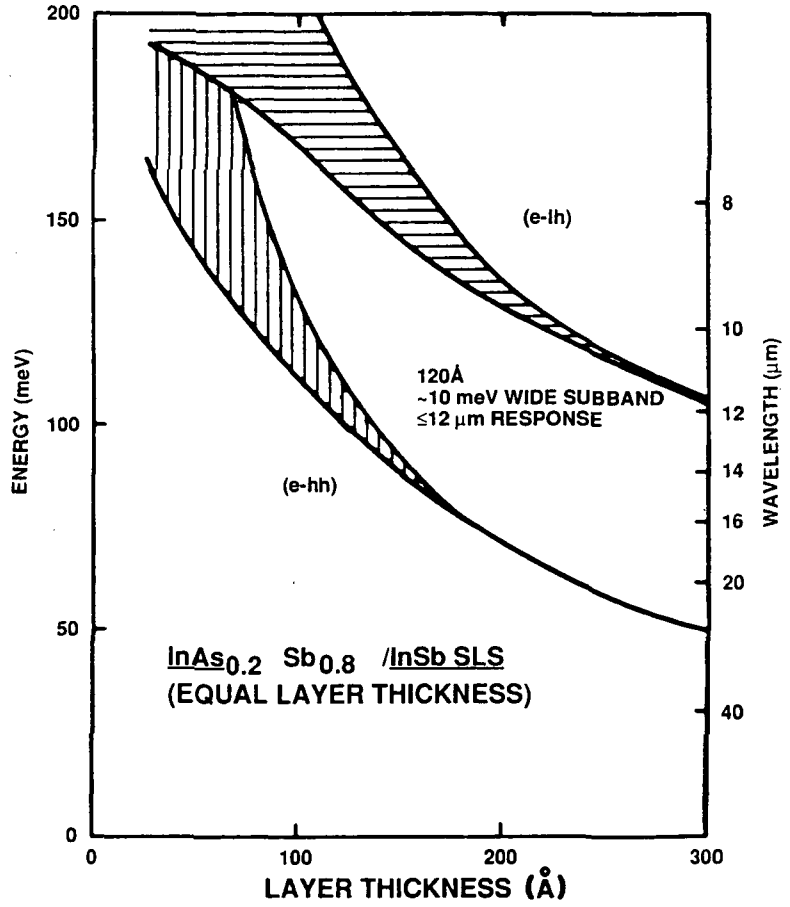
QUANTUM WELL STRUCTURE FROM PL DATA



Far IR Wavelength Accessibility of SLS InAsSb Detectors at 77K

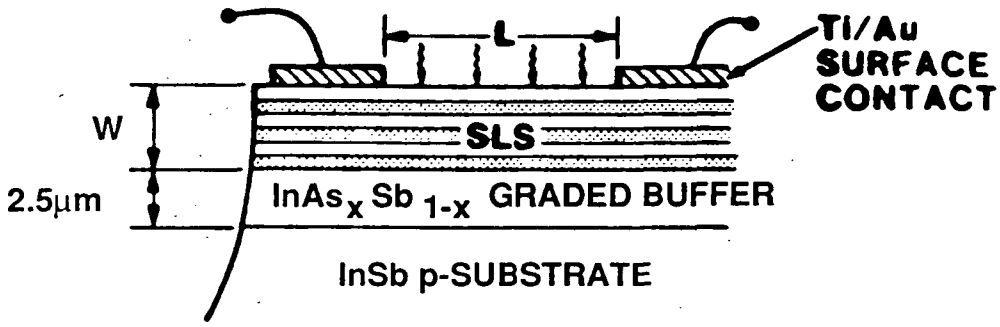


N=1 Transitions For 20% As SLS

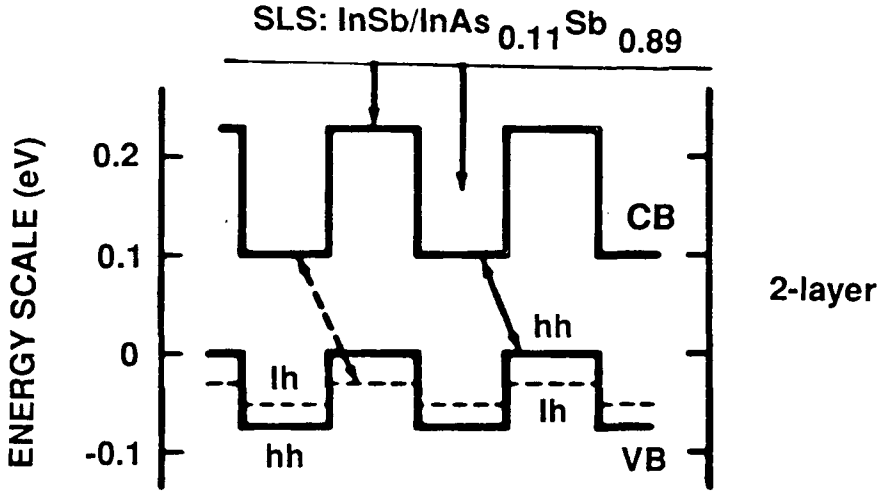


InAsSb SLS Photoconductive Detector

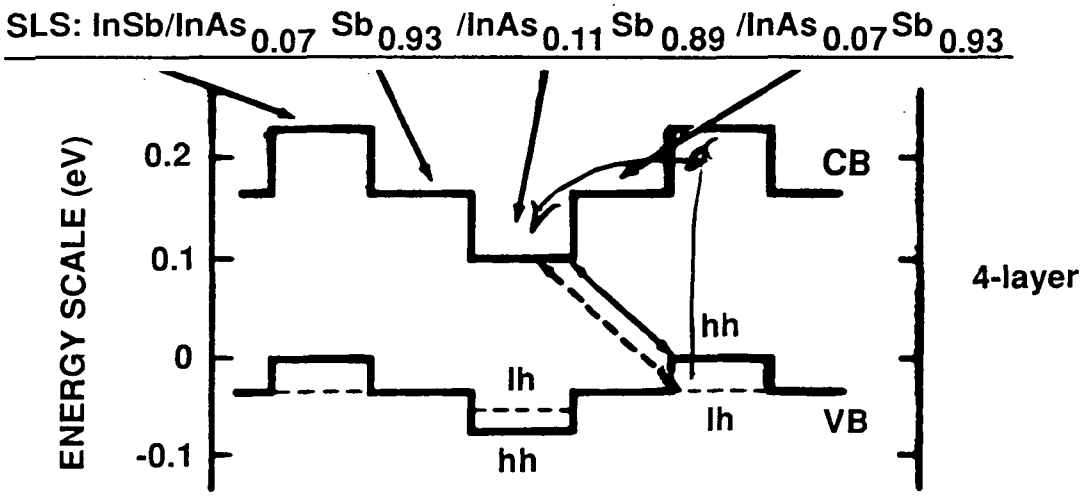
(a)



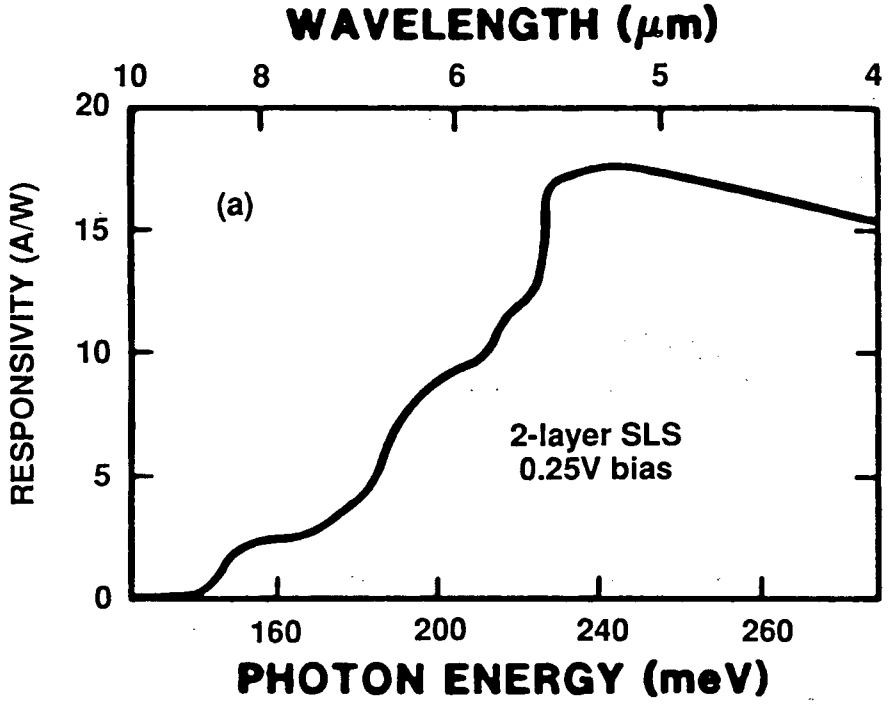
(b)

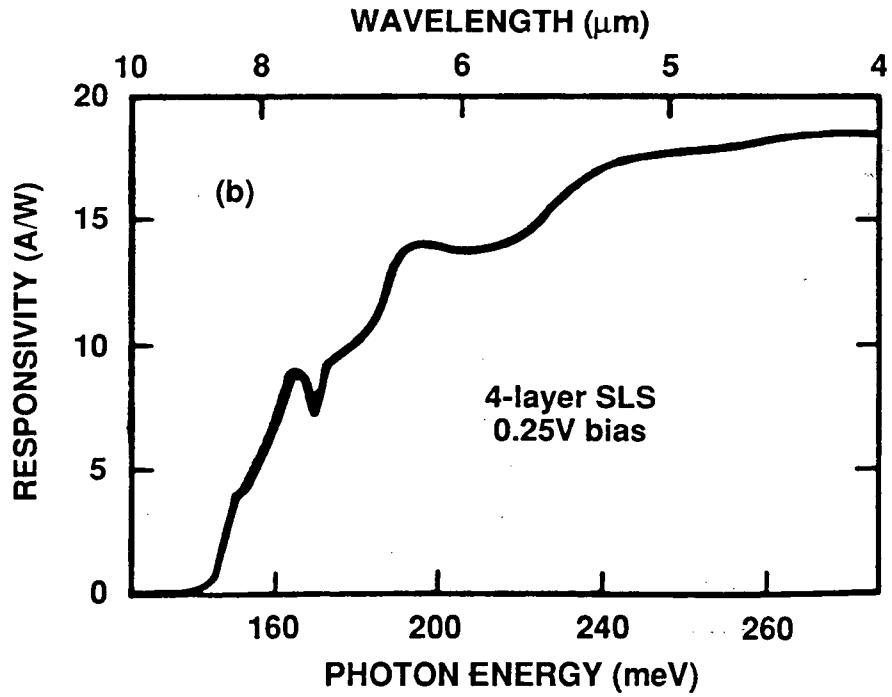


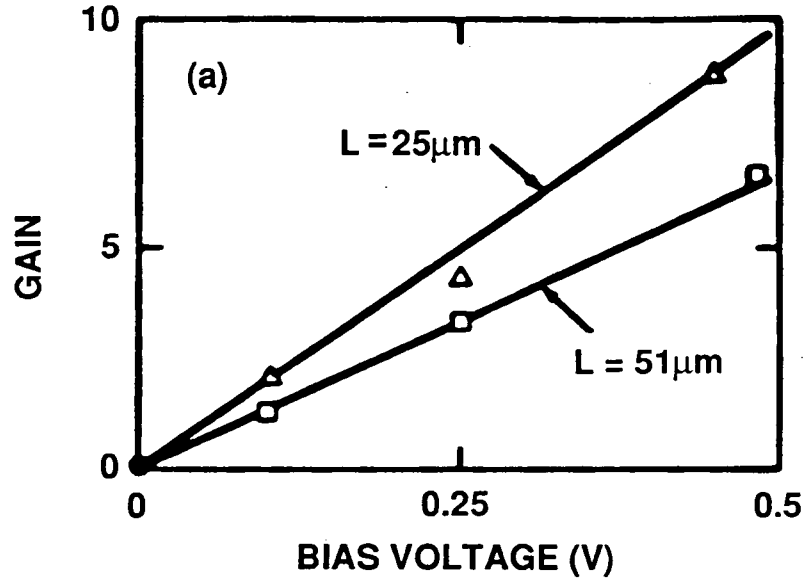
(c)

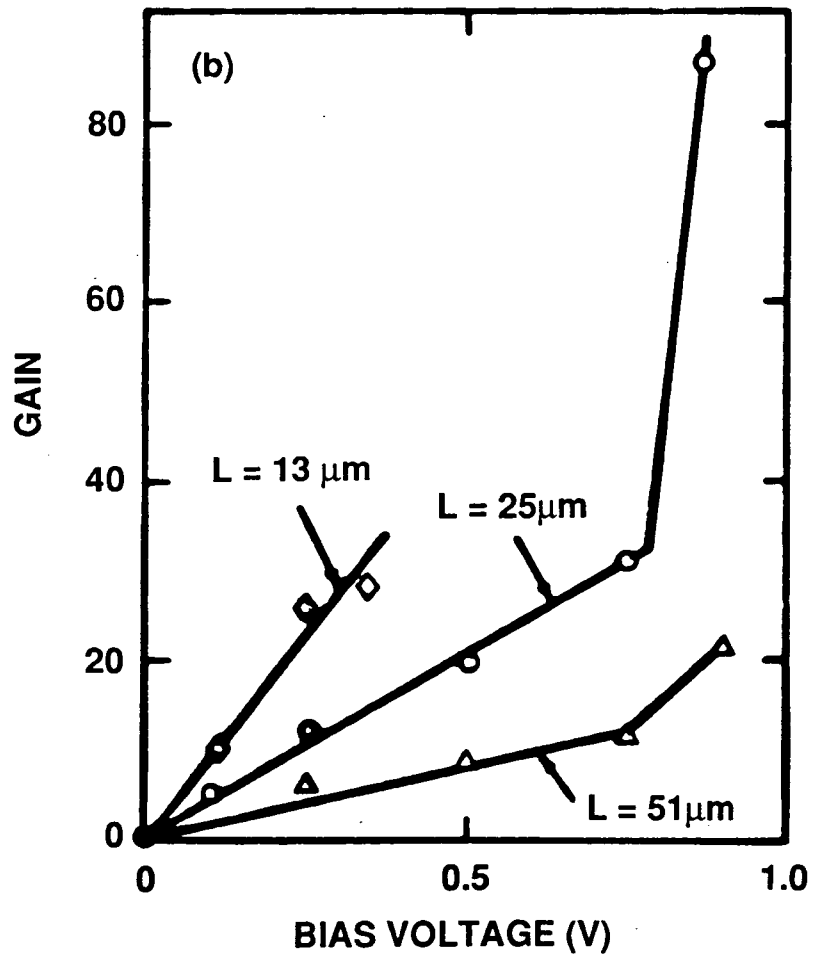


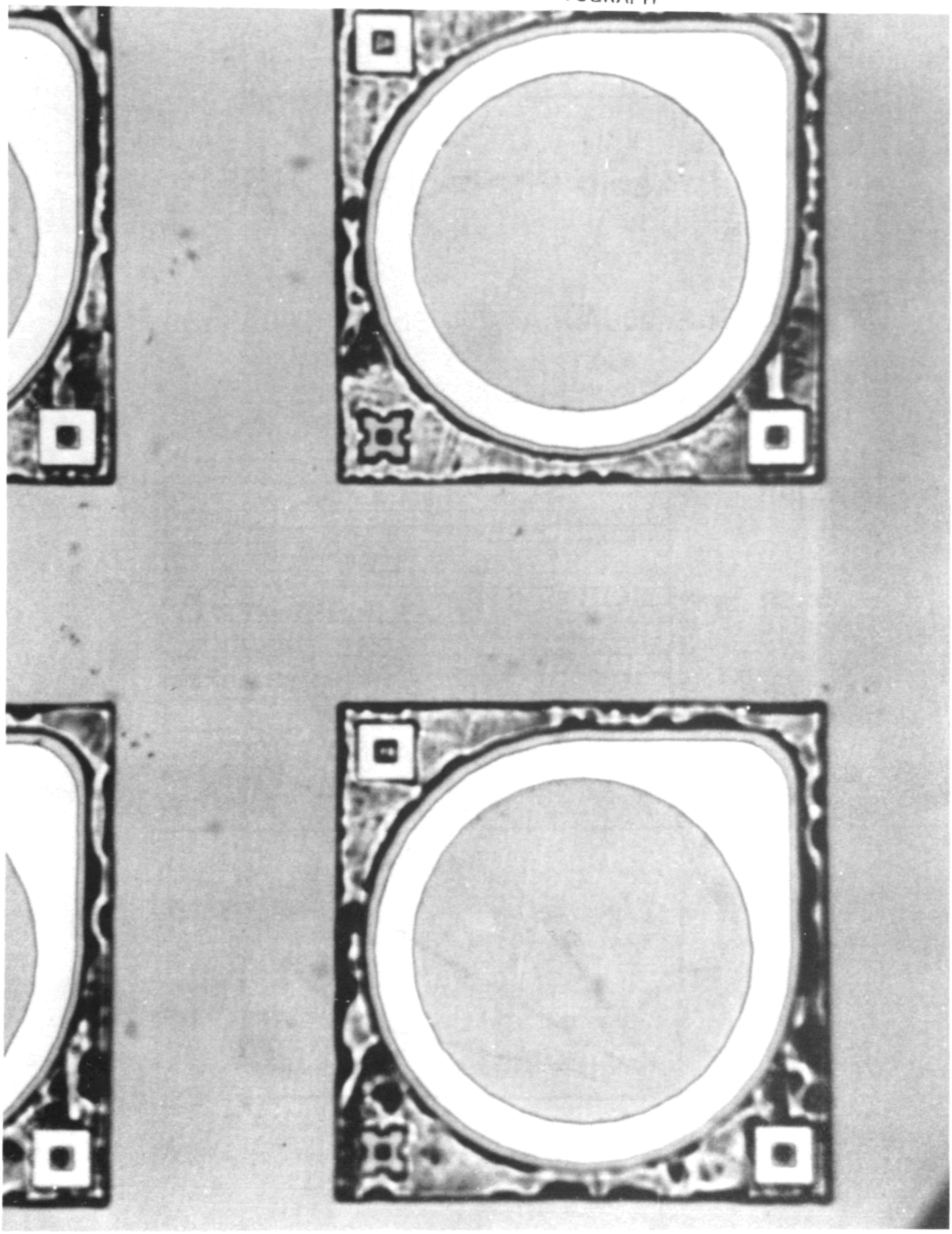
Photoconductive Detector Responsivity





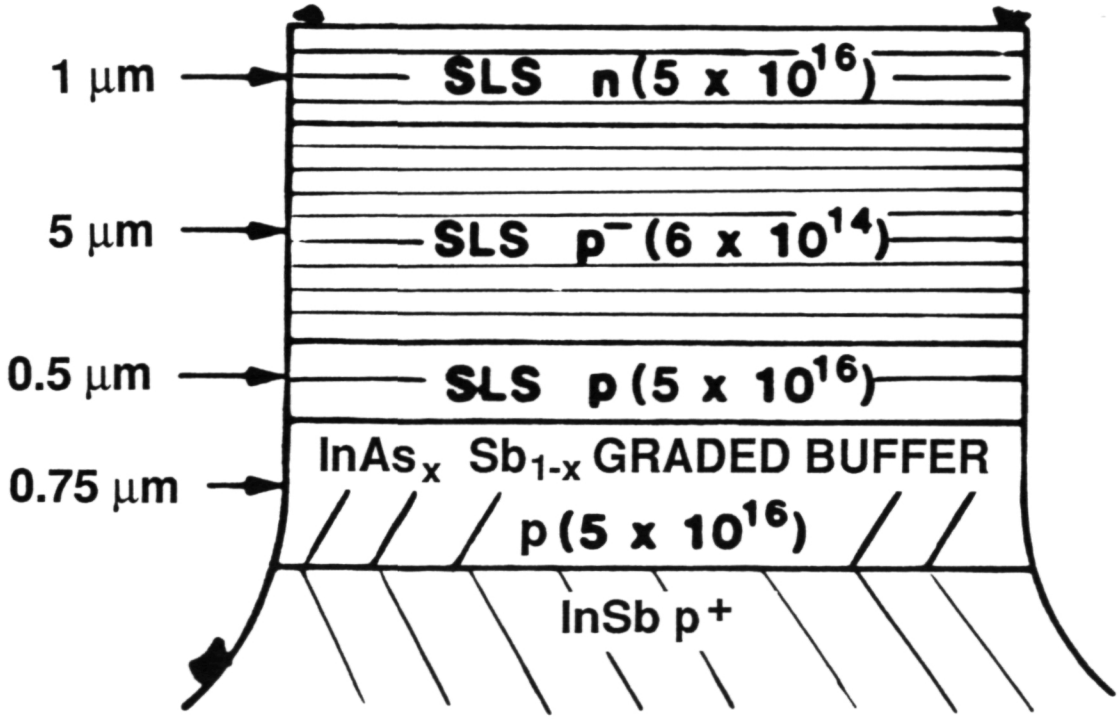

(a)
L = 25μm
L = 51μm
GAIN
10
5
0
0
0.25
0.5
BIAS VOLTAGE (V)

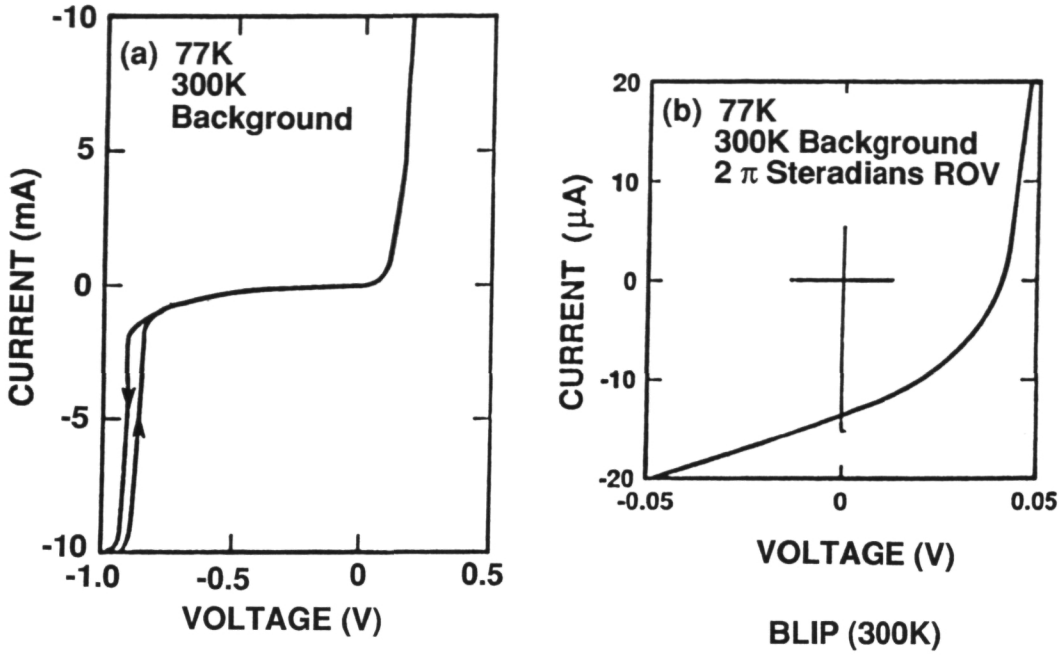

(b)
L = 13 μm
L = 25μm
L = 51μm
GAIN
80
60
40
20
0
0
0.5
1.0
BIAS VOLTAGE (V)

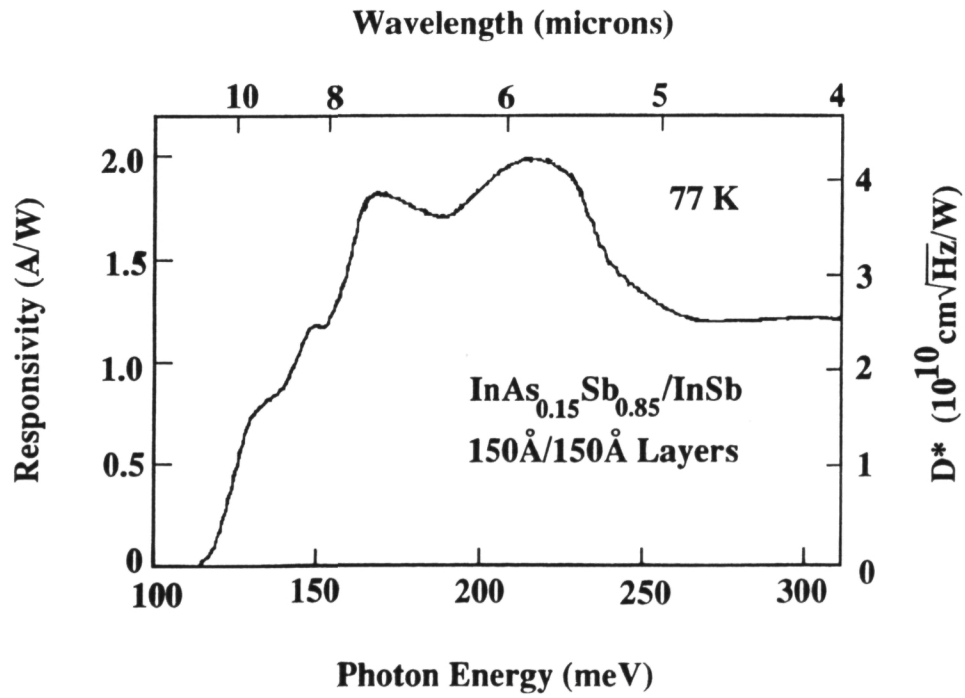


InAsSb Photodiode (MBE)

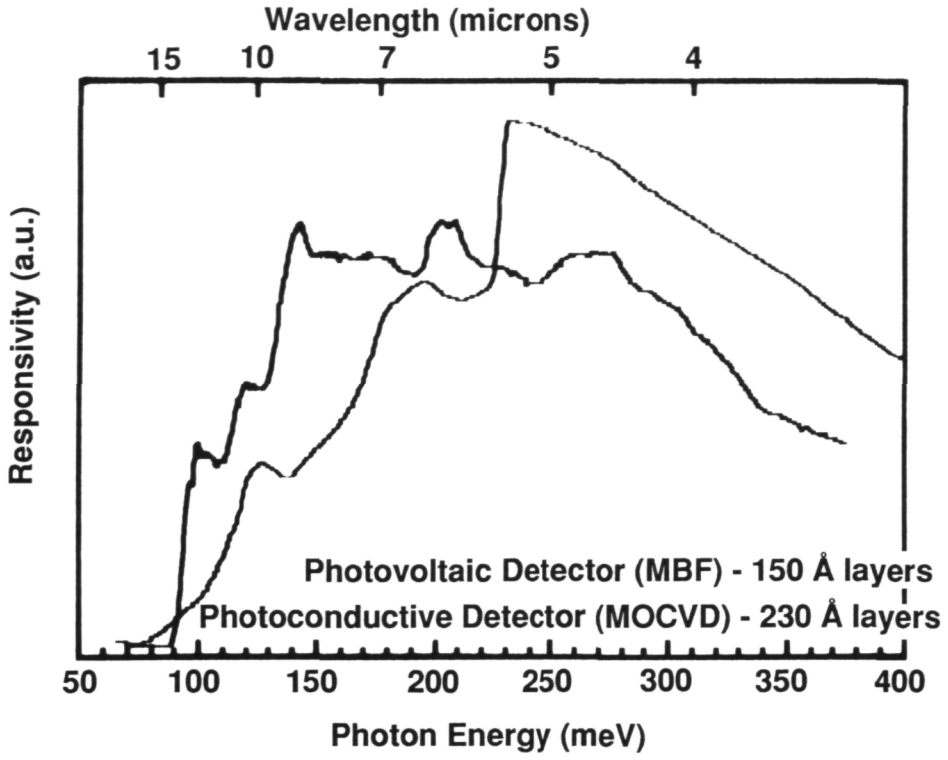
SLS: 200Å $InAs_{0.15}$ $Sb_{0.85}$ /200Å InSb




(a) 77K
300K
Background
CURRENT (mA)
VOLTAGE (V)
(b) 77K
300K Background
2 π Steradians ROV
CURRENT (μA)
VOLTAGE (V)
BLIP (300K)


Wavelength (microns)
77 K
InAs0.15Sb0.85/InSb
150Å/150Å Layers
Responsivity (A/W)
D* (10^10 cm√Hz/W)
Photon Energy (meV)

PHOTOVOLTAIC AND PHOTOCONDUCTIVE SLS DETECTOR PHOTORESPONSE TO 15 μm



PROCESS CONTROLS

- **On-line monitors and control during growth**

  REMS (MBE)

  UV absorption (MOCVD)

- **Monitor of superlattice quality**

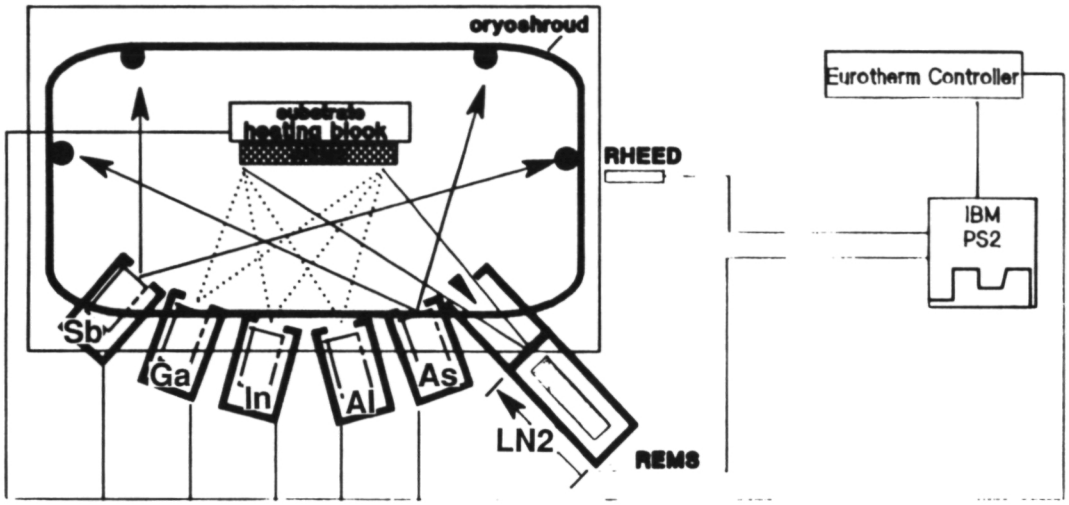
  Photoluminescence

Reflection Mass Spectometry and III/V MBE

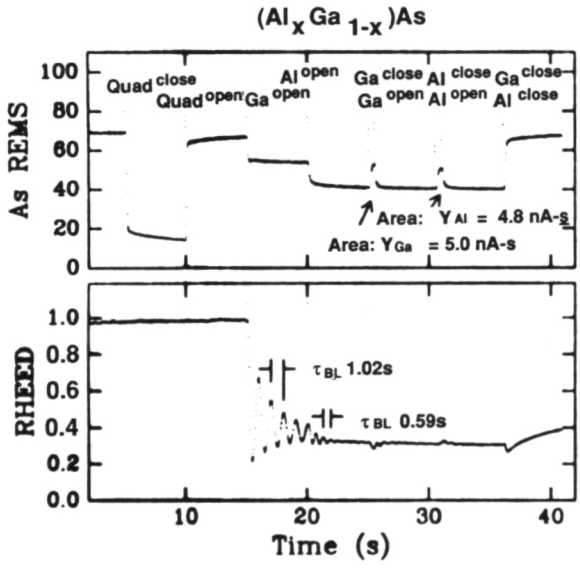
"REMS"

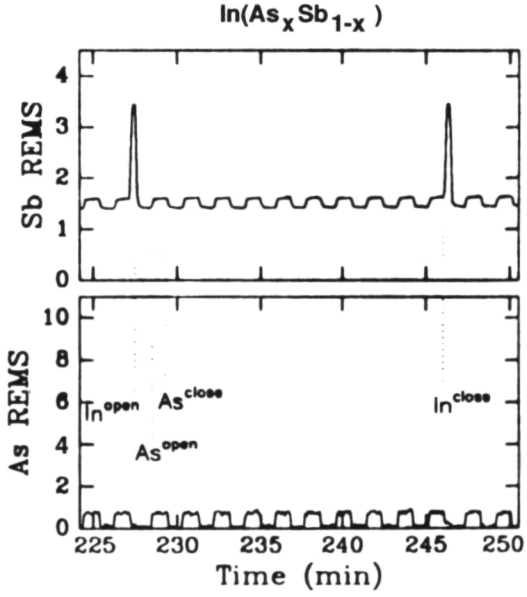
Jeff Tsao, Tom Brennan, Gene Hammons
Ray Hibray, John Klem, Ralph Dawson

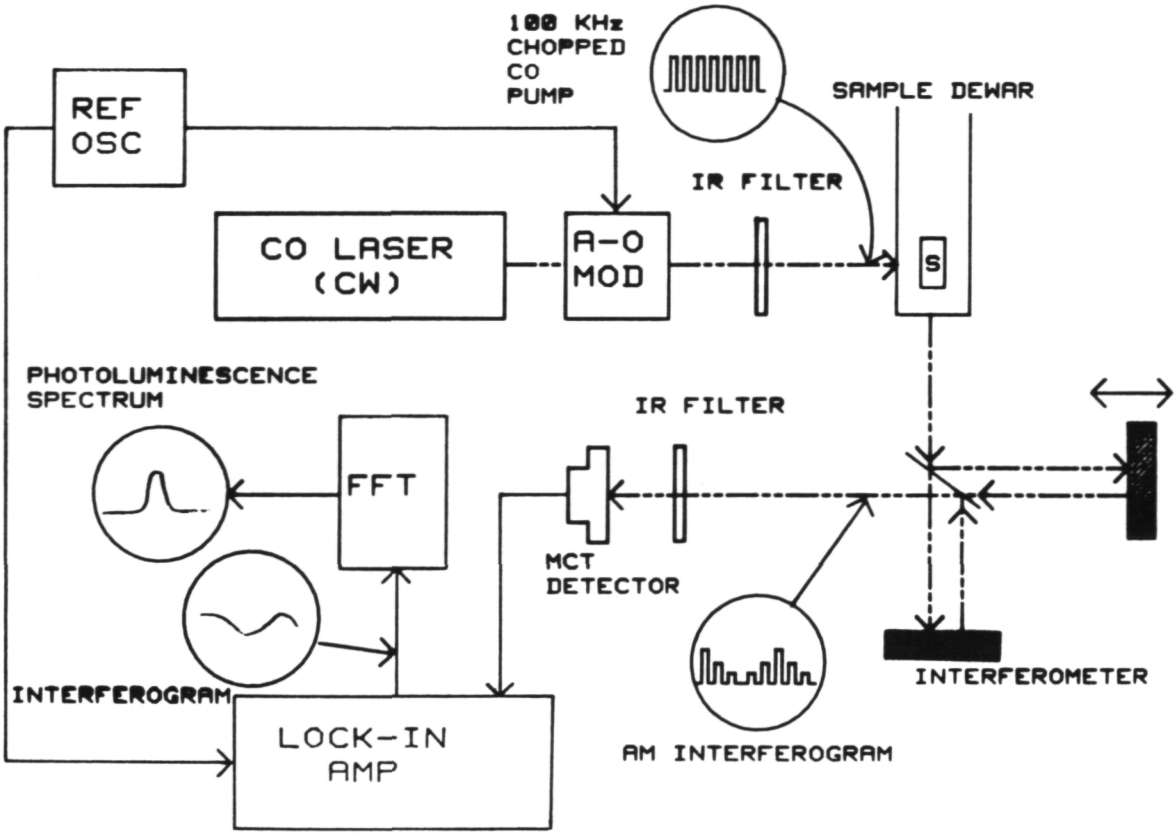
Riber, Varian and VG MBE systems



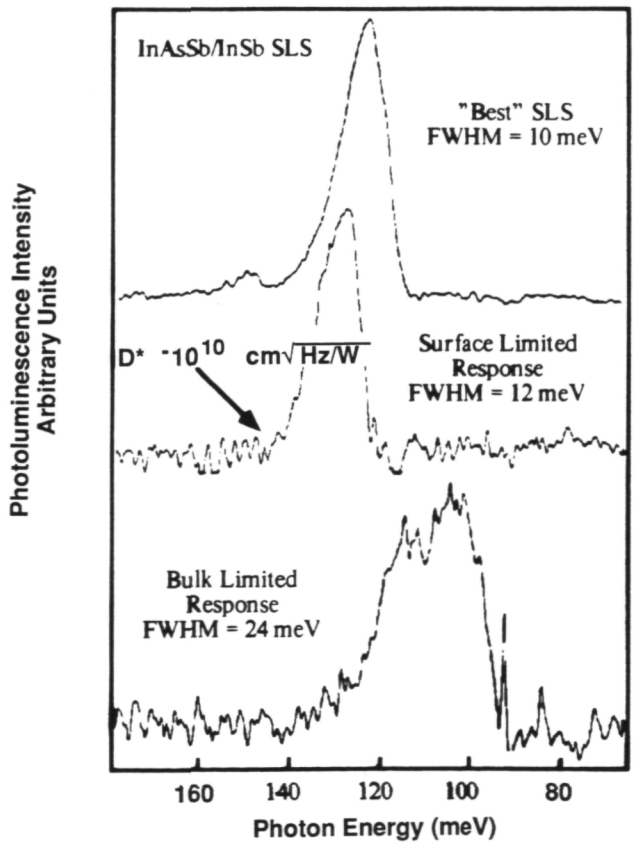
Composition Control using REMS







Photoluminescence Linewidth Characterization of Wafer Quality



PROCESSING TECHNIQUES

ETCHING – STANDARD WET-CHEMICAL TECHNIQUES USING STANDARD PHOTORESIST PROCESSES

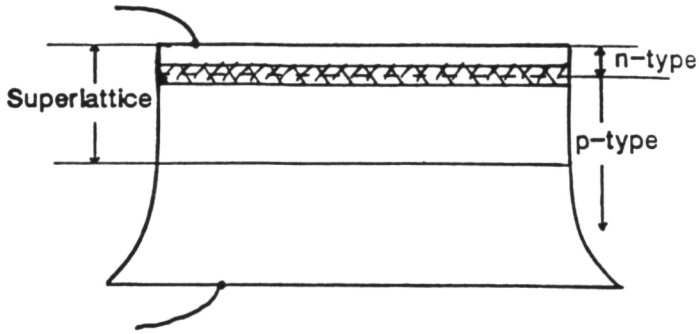
METALLIZATION – NON-ALLOYED Ti/Au OR Cr/Au OHMIC CONTACTS DEFINED BY CONVENTIONAL LIFTOFF TECHNIQUES

PASSIVATION – VARIOUS SCHEMES ARE BEING INVESTIGATED WITH POSITIVE RESULTS

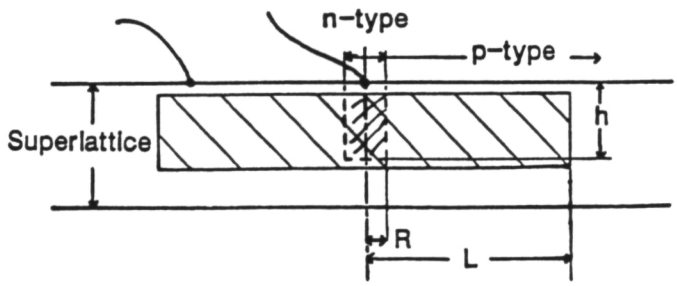
PACKAGING – STANDARD PACKAGES AND ADHESIVES WITH ULTRASONIC LEAD BONDING HAVE BEEN USED SUCCESSFULLY

INTERFACING – ISSUE NOT ADDRESSED YET

Superlattice Mesa Photodiode:



Lateral Superlattice Photodiode:



SUMMARY

- InAsSb SLS detectors can span the 8-15 μm spectral region
- LWIR photovoltaic detectors have been demonstrated with $D^* > 10^{10}$ cm√Hz/W at 10 μm
- LWIR photoconductive detectors with high gain have been demonstrated
- REMS and PL have been demonstrated to be valuable growth and process monitors