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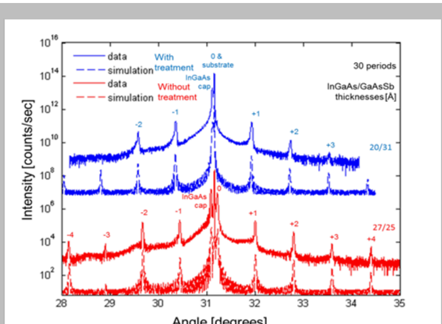

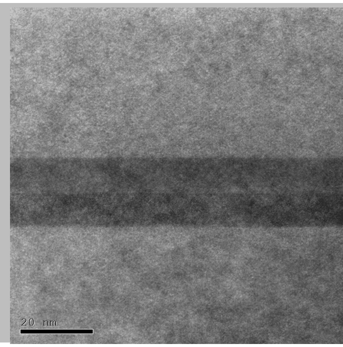

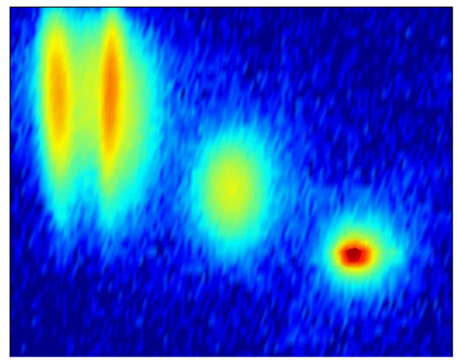

Efforts to improve interfaces during growth of GaAsSb/InGaAs heterostructures

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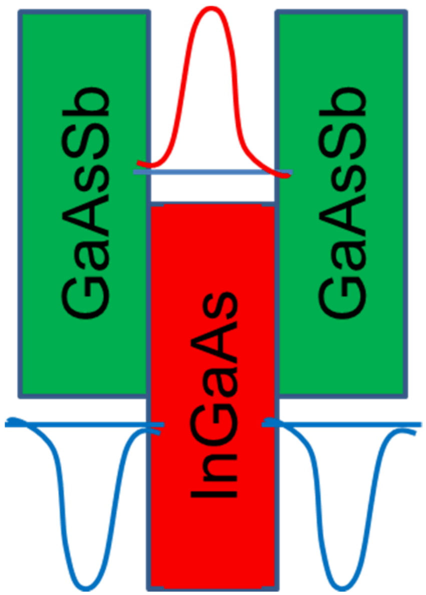
Why are we interested in GaAsSb/InGaAs heterostructures?

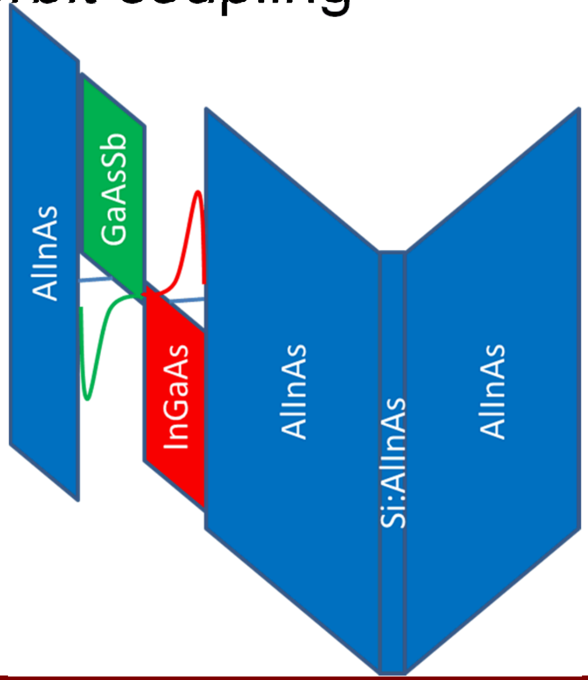
Type II staggered offset

- Allows energies less than constituent band gaps to be achieved



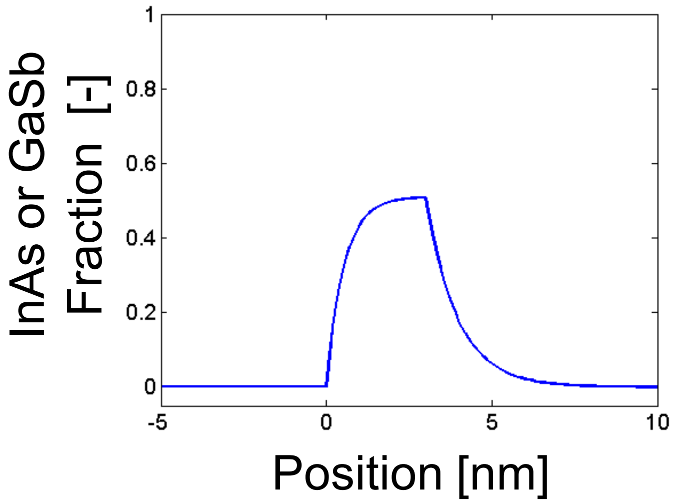
Large spin orbit energy

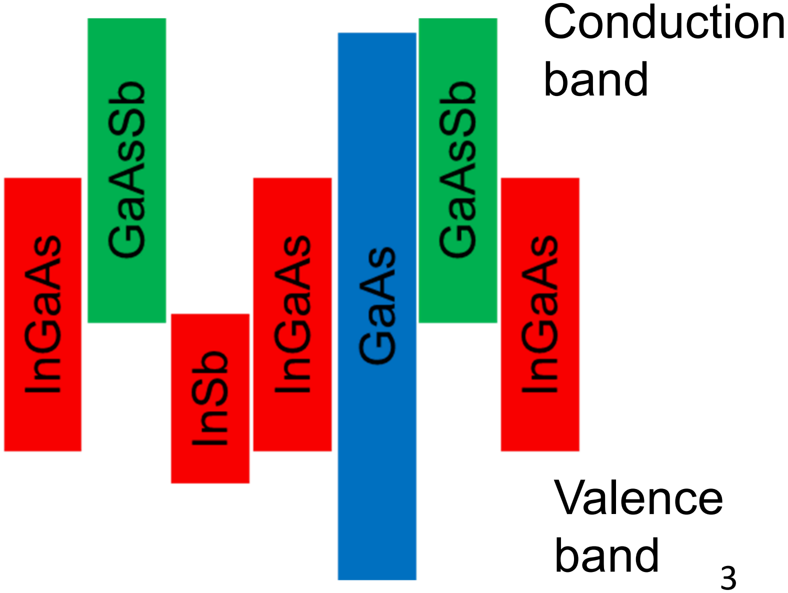
- Potential for electron spin polarization through spin-orbit coupling



What is the challenge? Achieving abrupt profiles

- In and Sb are known to have slower response for both accumulation and desorption
- Imposed on this is the chemistry of the deposition process
  - Temperature drives source molecule decomposition
- Results in compressive InSb-rich and tensile GaAs-rich interface layers can dominate properties



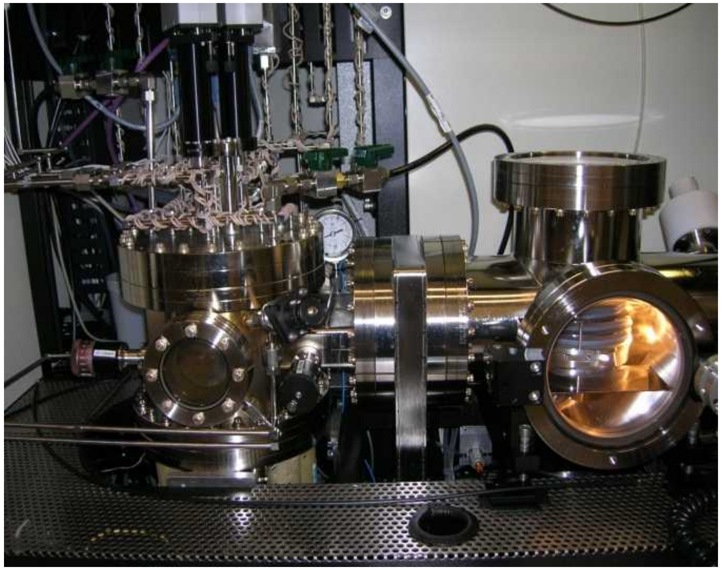


Outline

- Experimental details
- Ideal heterostructure characteristics
  - X-ray diffraction simulations
- Non-ideal interfaces
  - X-ray diffraction results
- InGaAs going to GaAsSb
- GaAsSb going to InGaAs
- Conclusions

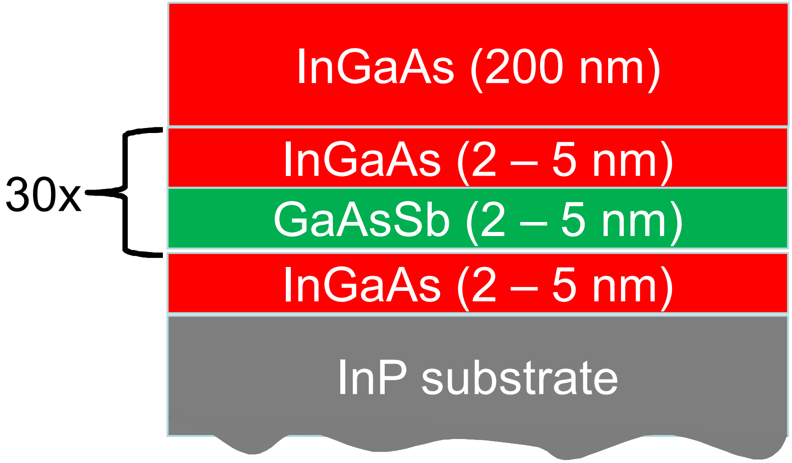
Growth details

- Grow structure using 60 Torr MOVPE in H_2
- InP buffer: TMIn and PH_3 at 620°C
  - Growth rate = 12 nm/min with V/III = 150
- AlInAs: TMIn, TMAl, and AsH_3
  - Growth rate = 24 nm/min with V/III = 70 at 660°C
- Temperature = 530 to 570°C
- InGaAs: TMGa, TMIn, AsH_3
  - Growth rate = 22 nm/min with V/III = 92
- GaAsSb: TEGa, TMSb, and AsH_3
  - Growth rate = 12 nm/min with V/III = 7, TMSb/AsH_3 = 3.7



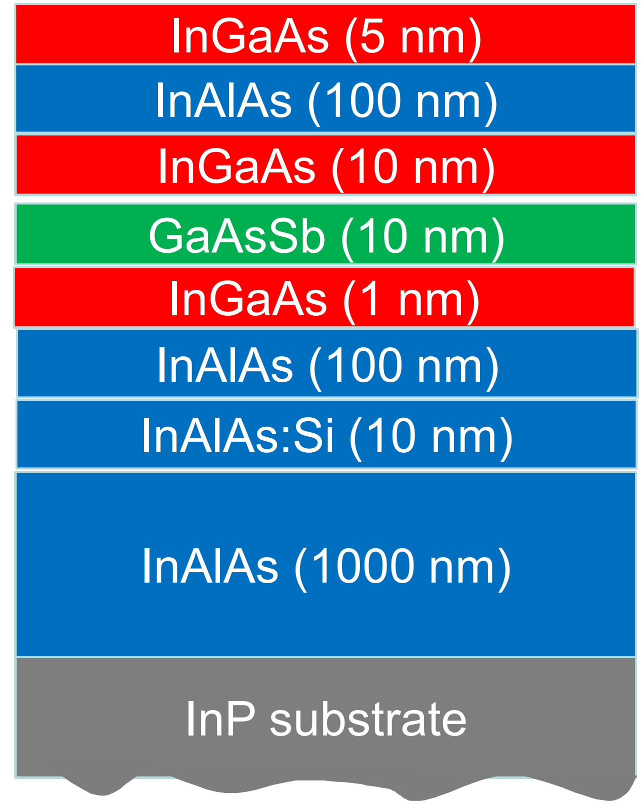
Structure and analysis details

1) MQW with cap



- XRD
  - Symmetric (004) Ω/2Θ scans
  - Interpreted with dynamic simulations
- Room temperature PL
  - Taken with FTIR system using 1550 nm excitation and InSb detector

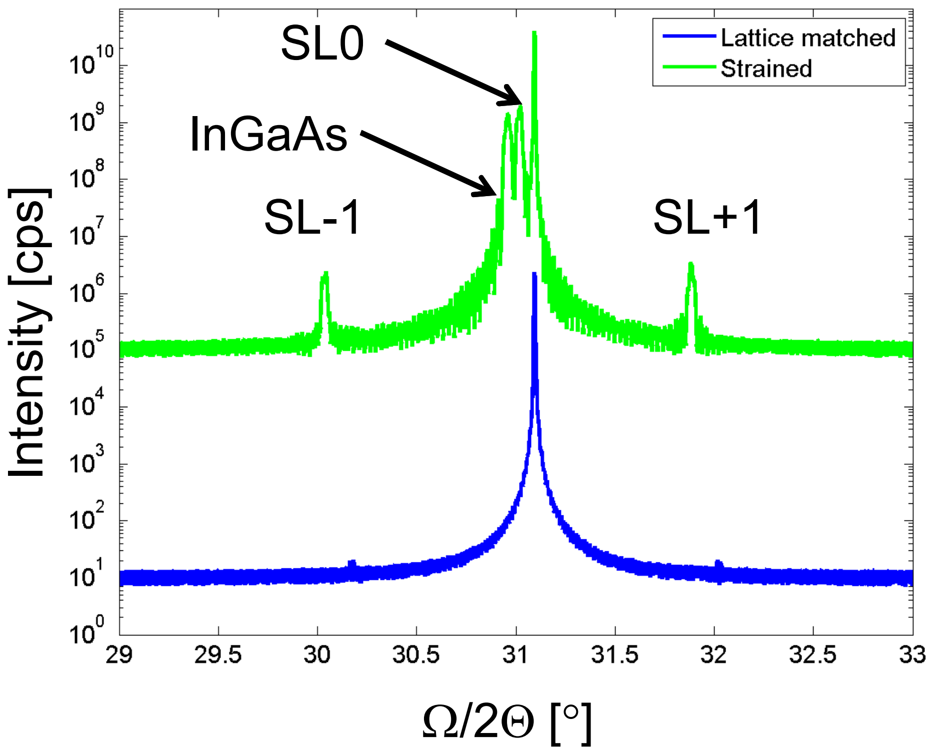
2) Quantum well channel



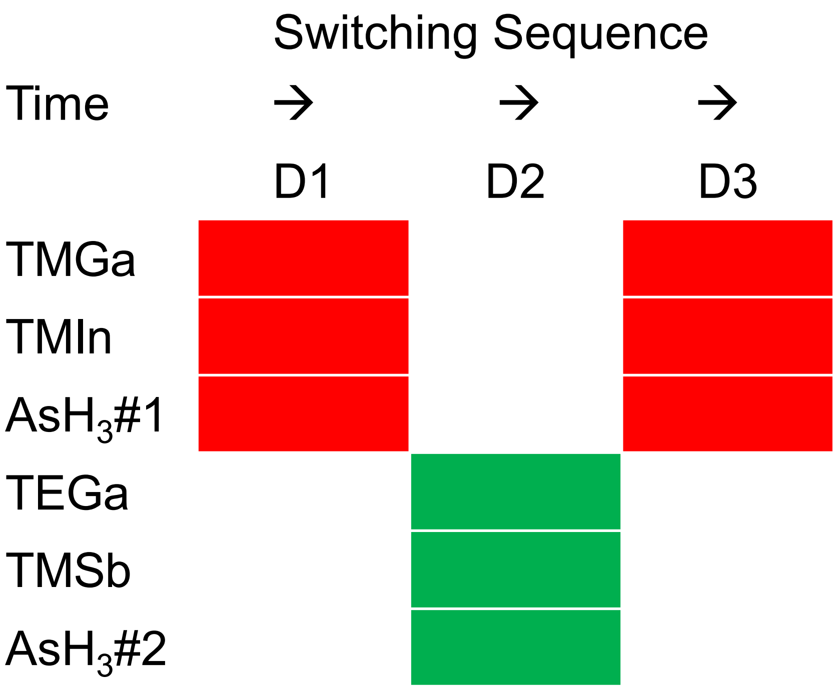
- XTEM
  - high resolution

Simulations of ideal MQW

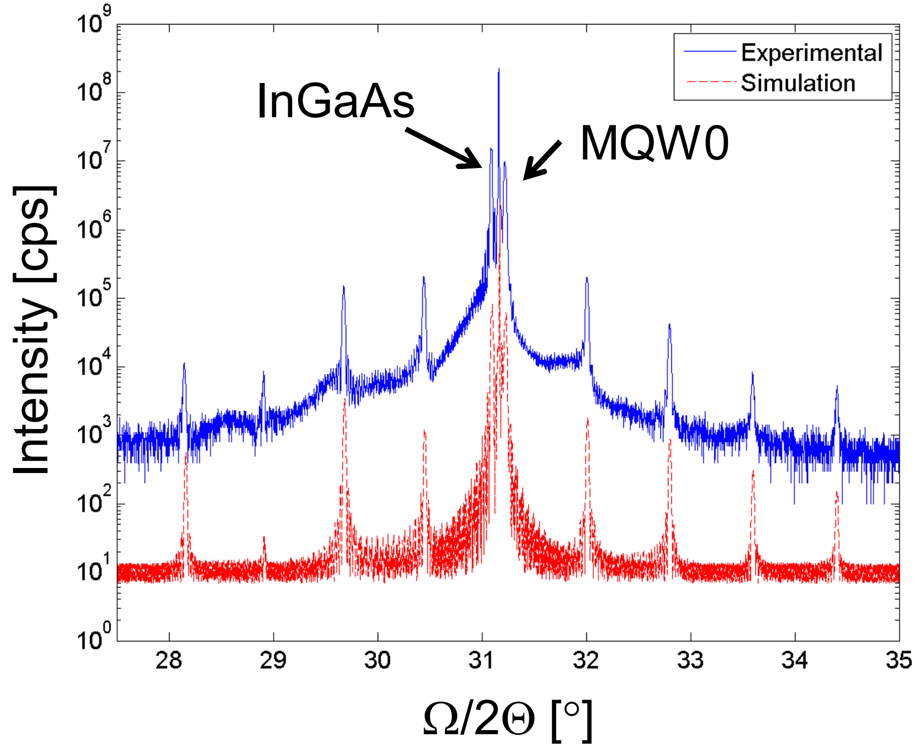
- Lattice matched InGaAs/GaAsSb have few features
  - Weak +/- 1 satellites are associated with small strain (< 50 ppm)
- Strain introduces expected features
  - +3000 ppm for InGaAs
  - +1000 ppm for GaAsSb



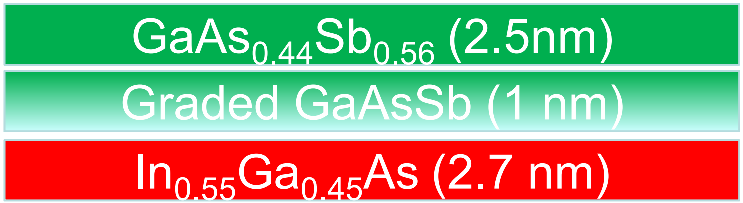
Initial MQWs - nonidealities



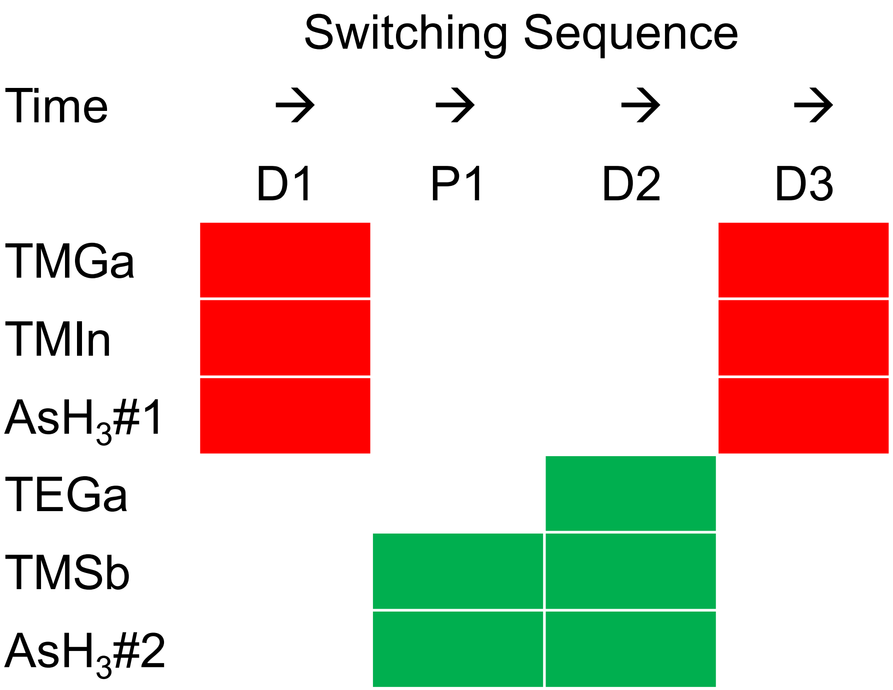
- MQW is in tension
- Graded GaAsSb layer varies from GaAs to $GaAs_{0.44}Sb_{0.56}$
- Additional non-monotonic intensity envelope observed at higher angle

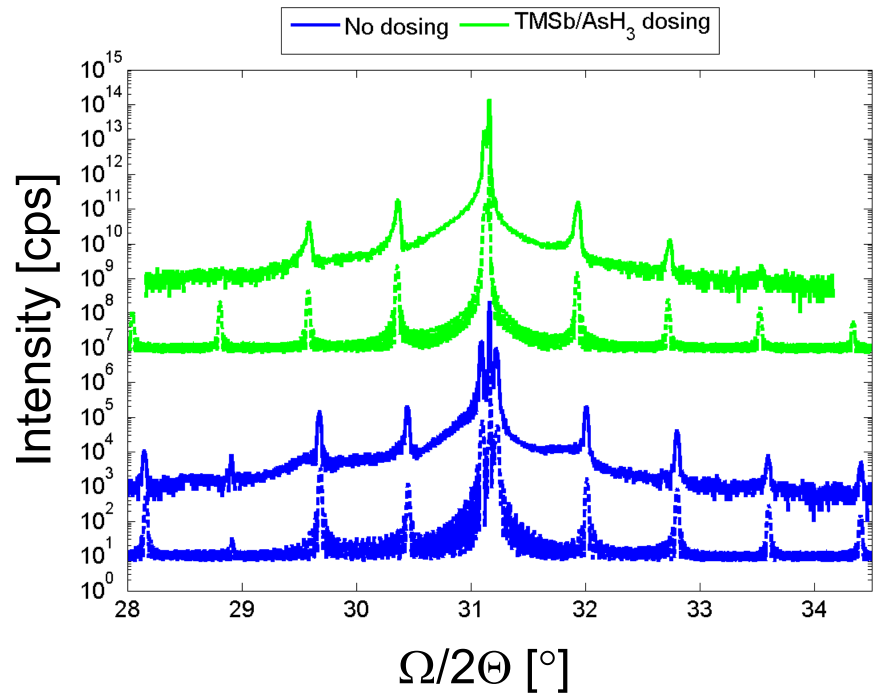


Period of simulated MQW



TMSb/AsH$_3$ dosing of InGaAs surface



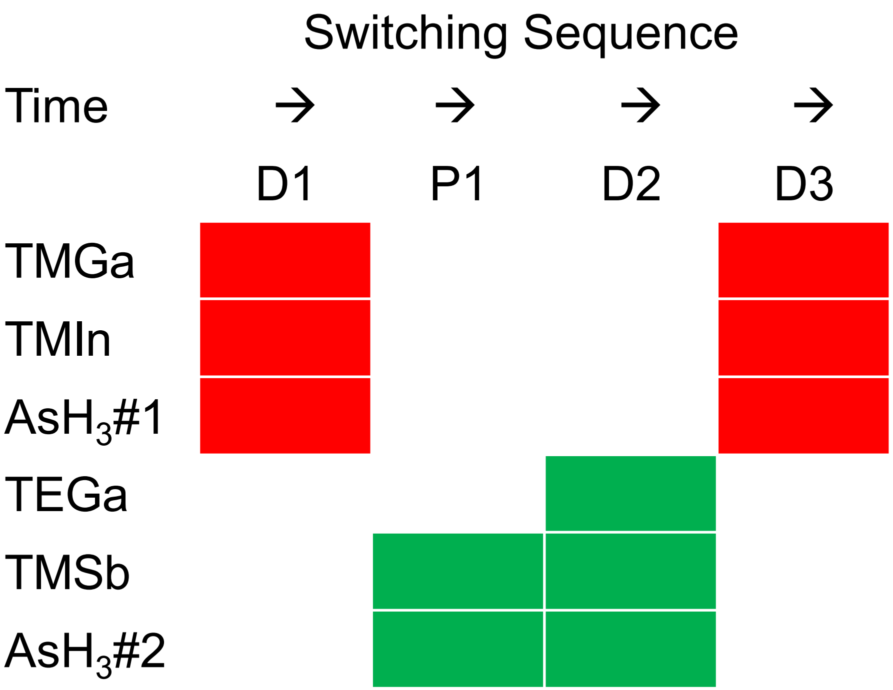


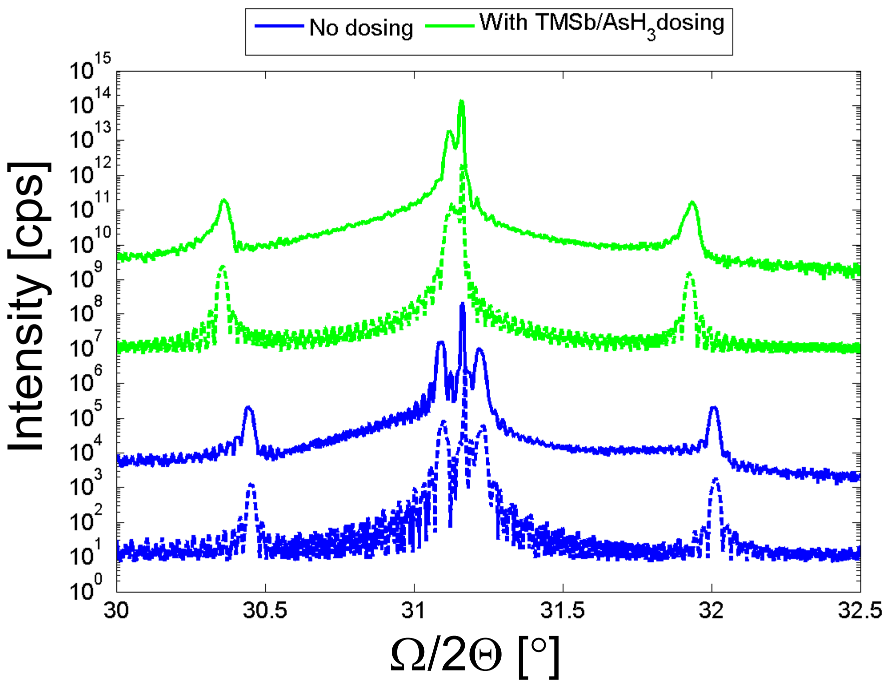
- Investigated P1 from 3 to 24 s
  - Found 12 s worked well
- Dosing reduces, but doesn't eliminate strain

Period of simulated MQW

$GaAs_{0.47}Sb_{0.53}$ (3.1 nm)
Graded GaAsSb (0.1 nm)
$In_{0.54}Ga_{0.46}As$ (2 nm)

TMSb/AsH$_3$ dosing of InGaAs surface





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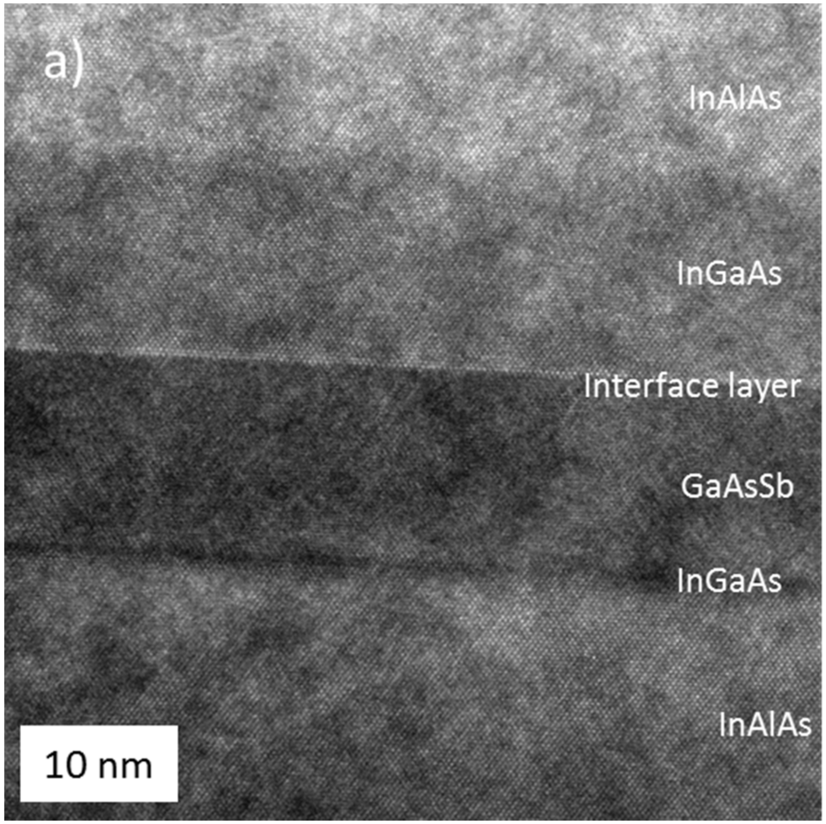
Graded GaAsSb (0.1 nm)

$In_{0.54}Ga_{0.46}As$ (2 nm)

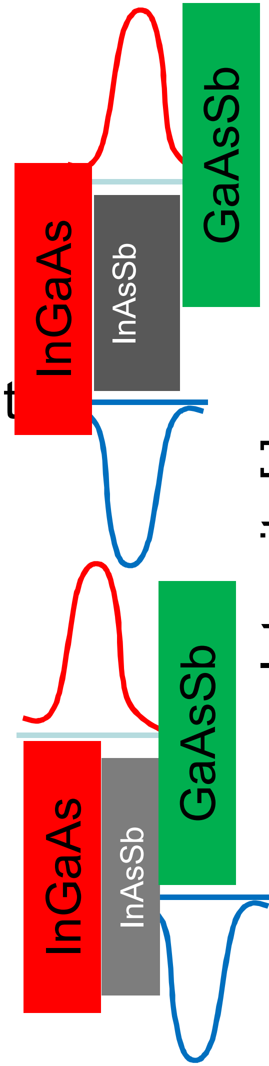
XTEM on QW channel structure

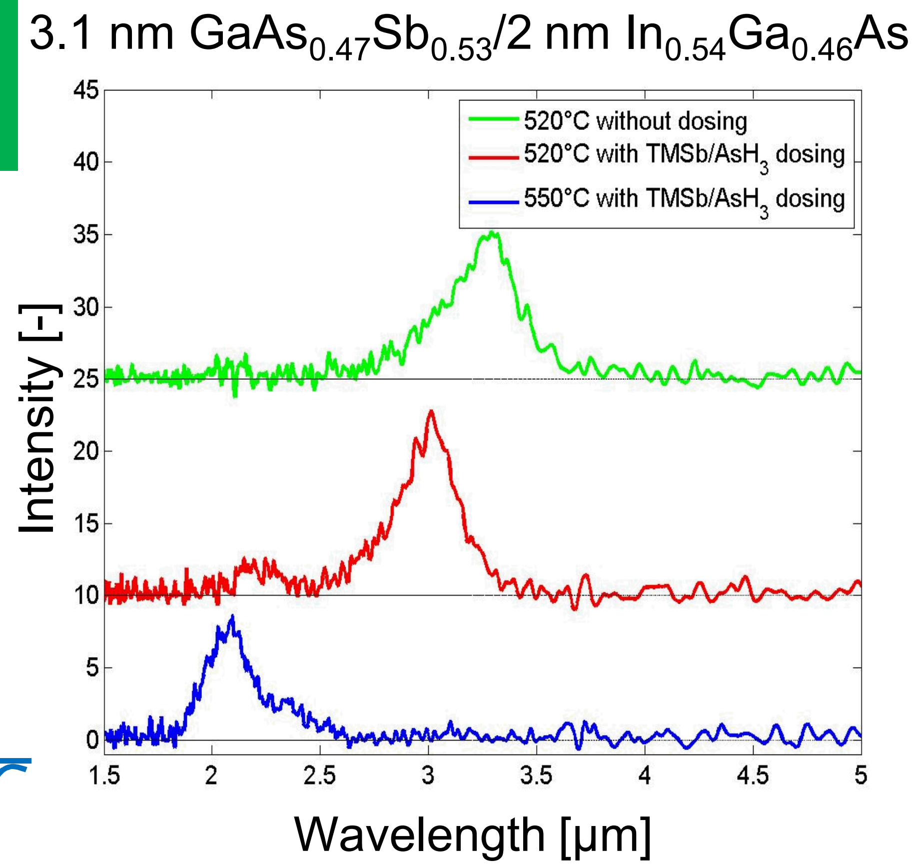
- Using optimized TMSb/AsH_3 purge
- High resolution images are sensitive to difference in electron phase
  - Phase differences can be caused by strain
- Concluded that tensile layer is on opposite side of GaAsSb
  - GaAs-rich interface



PL on MQWs

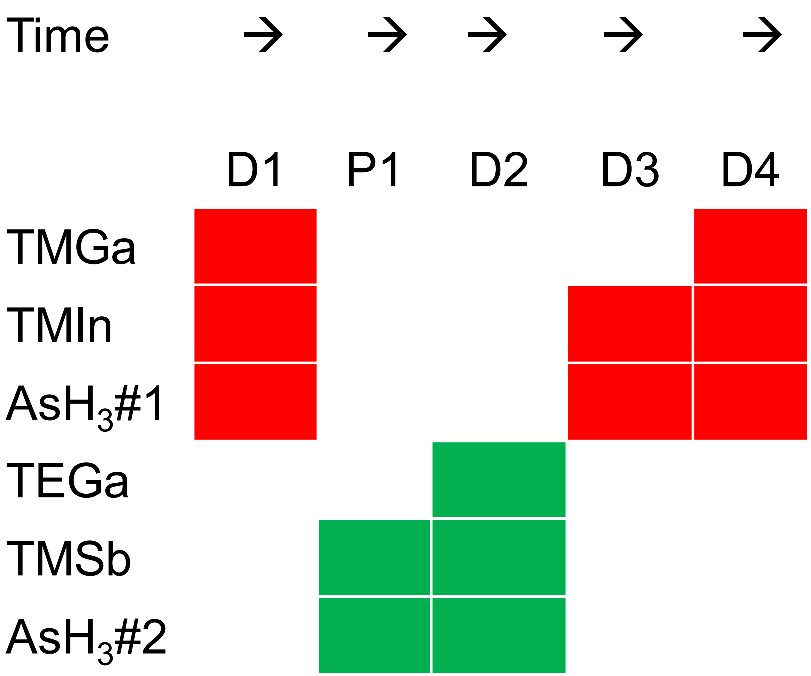
- Samples grown at 520^{0}C show 3+ μm emission
  - Wavelength inconsistent with thicknesses and compositions
  - Attribute to interfacial InAsSb dominating recombination
- Samples grown at 550^{0}C emit at 2 μm
  - Shoulder at 2.4 μm
- Found 570^{0}C was too warm for bulk GaAsSb growth

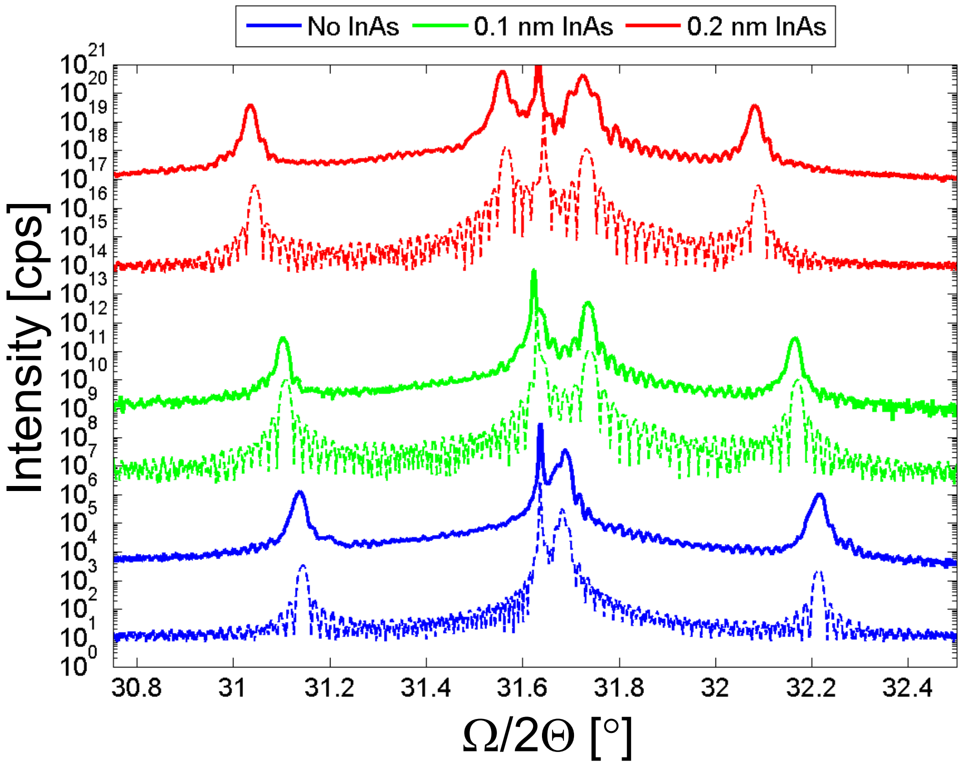




Further strain reduction – InAs layers

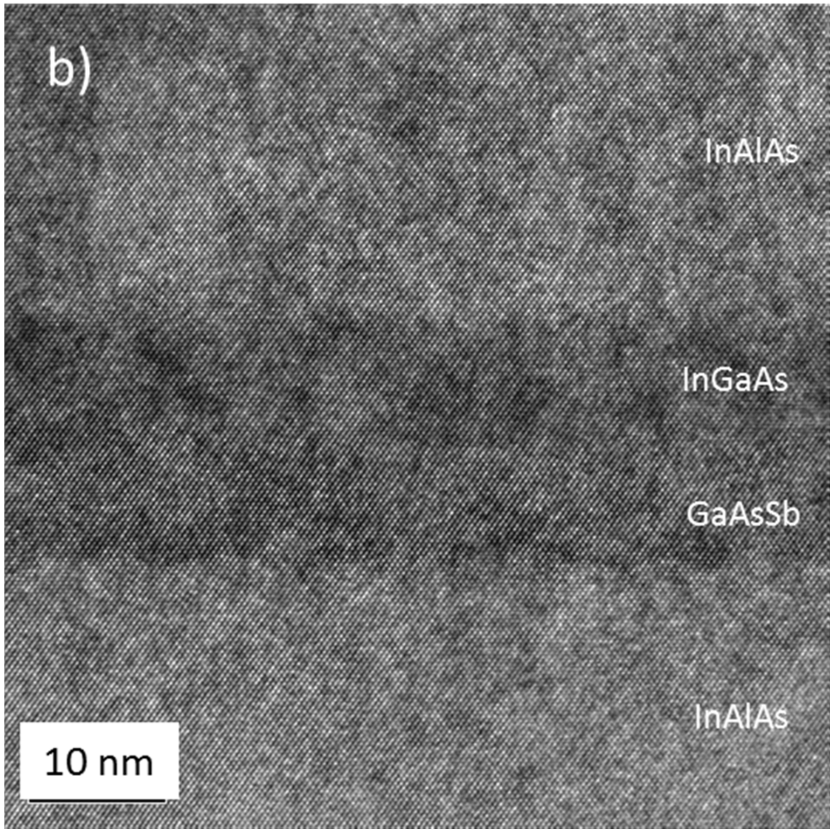
- Grow thin layers of InAs on top of GaAsSb
  - 0.1 nm optimal





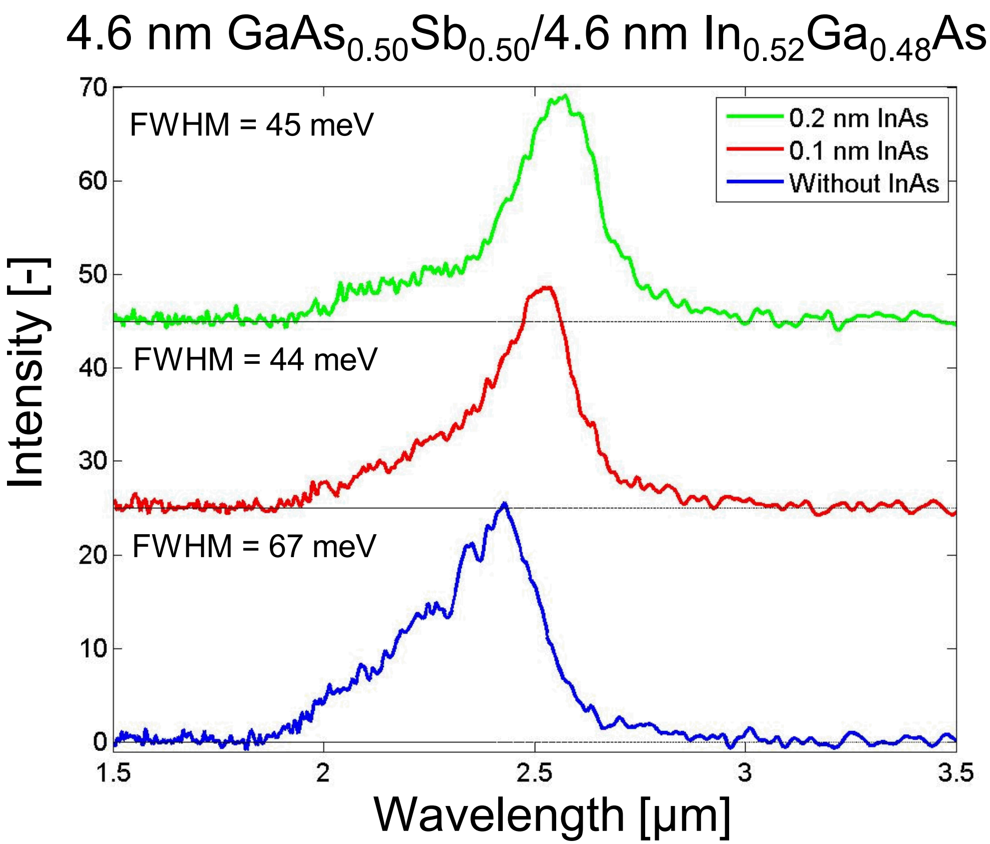
XTEM on improved structure

- InAs growth eliminates transition at GaAsSb to InGaAs interface
  - Small contrast between InGaAs and GaAsSb consistent with matched compositions
  - Contrast consistent with mass density



PL on InAs interface layer series

- Slight red-shift as thickness of InGaAs is increased
- Linewidth decreases with addition of InAs



Conclusions

- InGaAs/GaAsSb represent a challenging system to achieve ideal heterostructures
- Sb-incorporation limits abruptness going from InGaAs to GaAsSb
- PL dominated by interfaces
  - Low band gap InAsSb dominates PL at low growth temperatures
  - Higher growth temperatures improves optical properties
- In-incorporation limits abruptness going from GaAsSb to InGaAs
- PL characteristics are improved by optimized interfaces