Growth by MOVPE of AlGaN/GaN structures with intersubband transitions in the 1.2-1.7μm region of the spectrum

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Outline

- Motivation
- Design
- Growth
- Electron microscopy
- Absorption
- Conclusions

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Motivation

- C.B. Offsets in AlN/GaN system 1.8eV
- THz modulation rates at Telecom wavelengths possible

  But:- no device yet despite 10 years of research
- Difficult material system –highly strained, piezoelectric fields and high dislocation densities
- MBE used for previous studies

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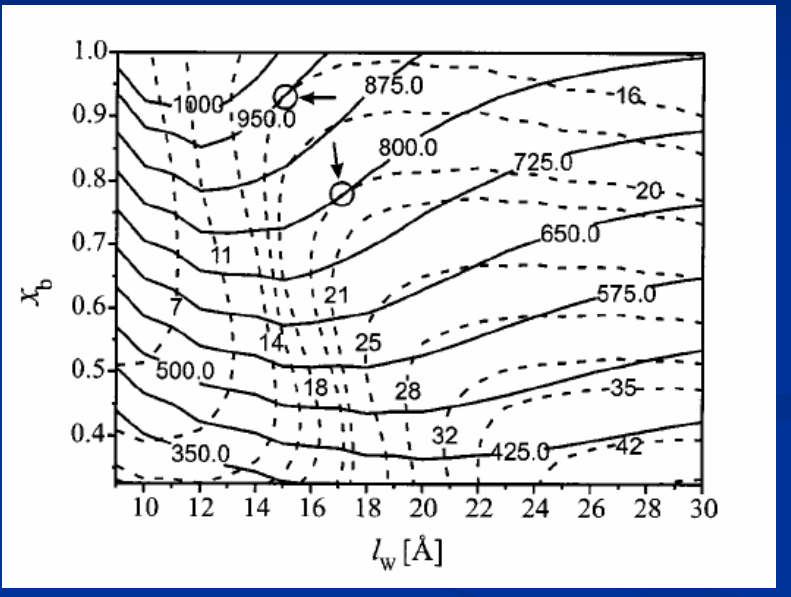
Why MOVPE?

- Against:-
  - High growth temperatures
  - Widely divergent optimum growth conditions

  GaN Tg<700°C AlN Tg>1000°C
- For:-
  - Rapid improvements in Technology due to mass production of Blue LEDs and Lasers
  - Cheap technology for mass produced devices

Minimizing Al in Barrier

V. D. Jovanovic, Z. Ikonic, D. Indjin, P. Harrison, V. Milanovic, and R. A. Soref J. Appl. Phys. 93, 3194 (2003)



- Assume barrier thickness 1nm
- Plot E_1-E_2 energy counters as function of barrier Aluminium fraction and well width

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Design

- Optimal growth conditions for AlN and GaN divergent, therefore $Al_{0.7}Ga_{0.3}N$ chosen for barrier material as compromise
- Two designs grown with differing doping levels
- Aim to achieve E_1-E_2 transitions at 1.5μm and E_1-E_3 at 1.3μm

Sample number	GaN well (nm)	$Al_{0.7}Ga_{0.3}N$ barrier (nm)	Repeats	Doping level electrons/cm^3
1	1.2	1.0	300	$1x10^{17}$
2	1.6	1.0	300	$1x10^{17}$
3	1.2	1.0	300	$3x10^{17}$

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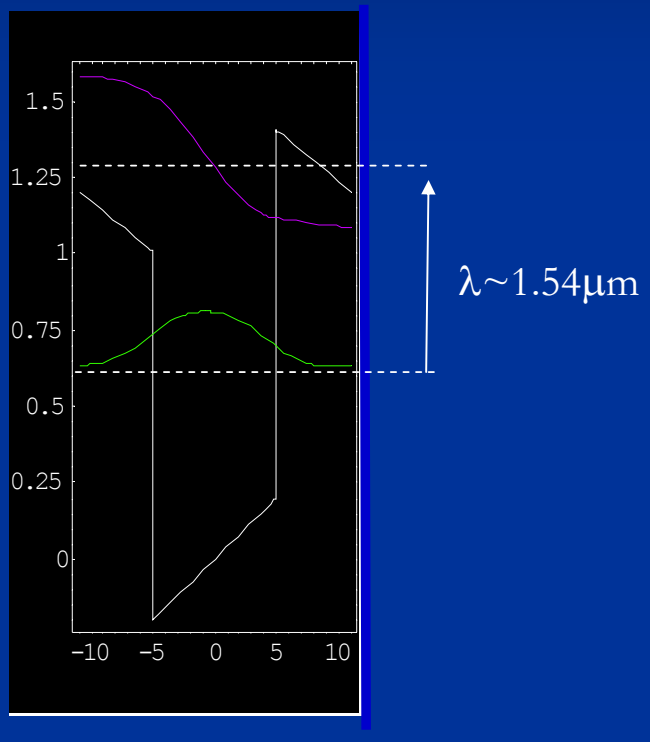
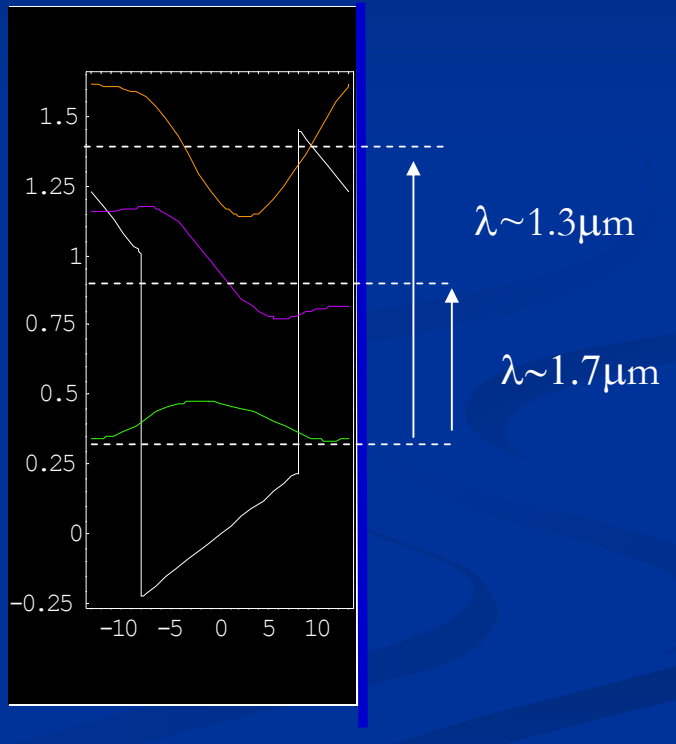
Potential profiles





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Growth

- Growth by standard shower head MOVPE reactor on sapphire
- High temp AlN grown on Sapphire first
- $Al_{0.3}Ga_{0.7}N$ 10nm strain balancing interlayer
- Compressive strain at base of superlattice relaxed by interlayer
- X-ray used to confirm structure

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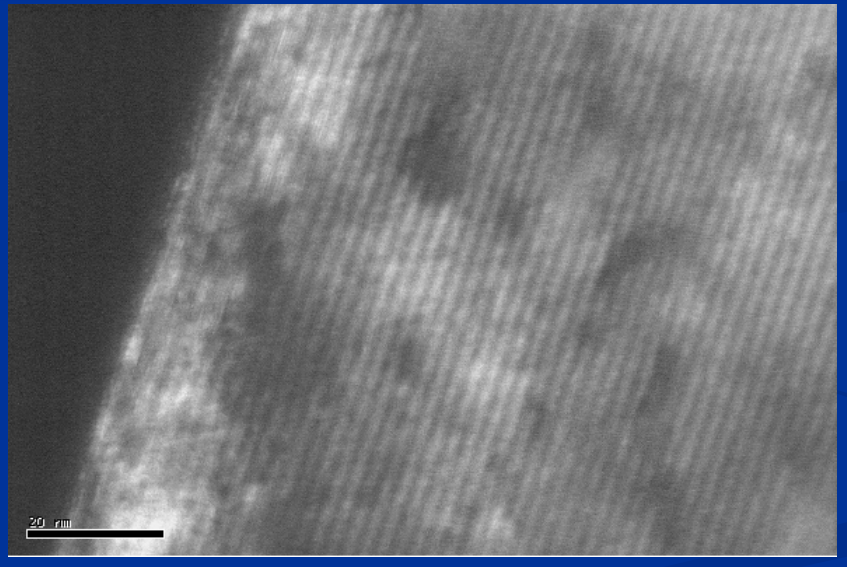
Electron microscopy

Top of superlattice



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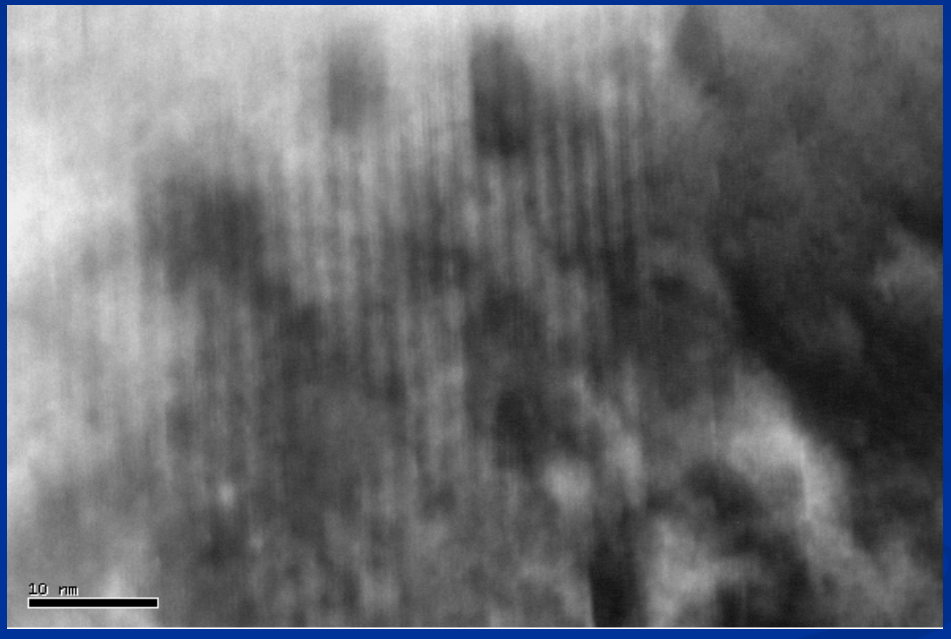
AlN buffer Region



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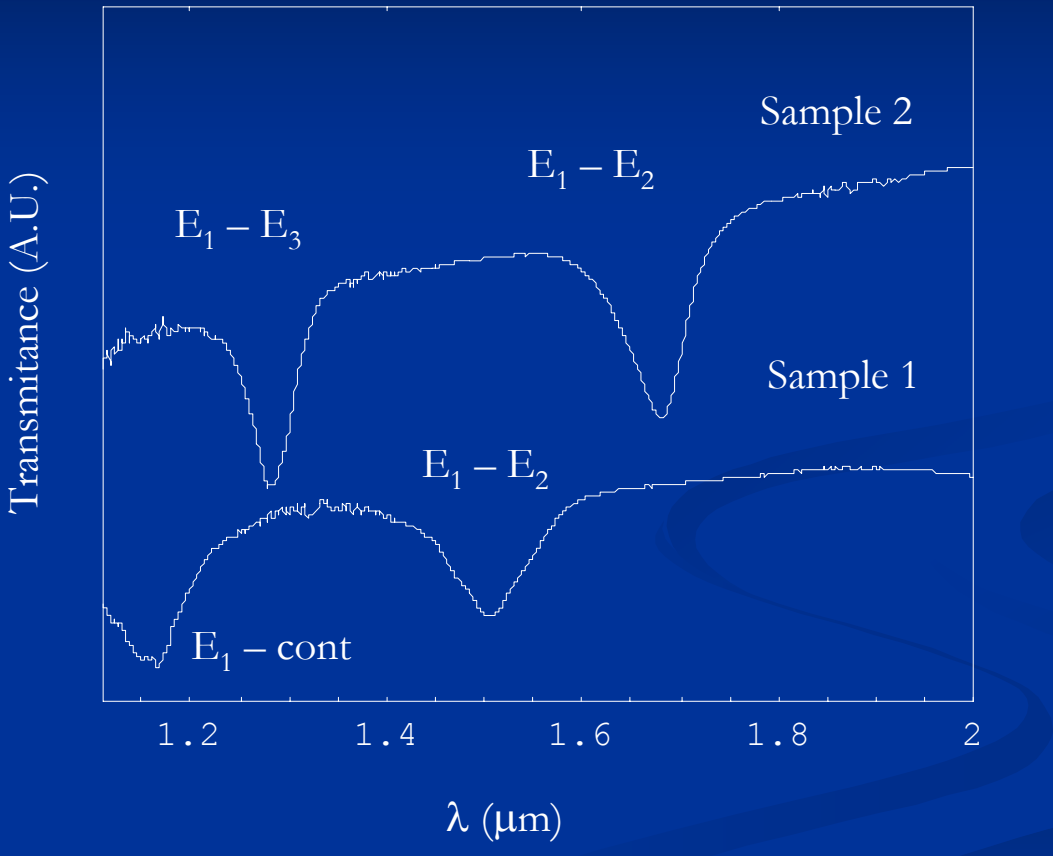
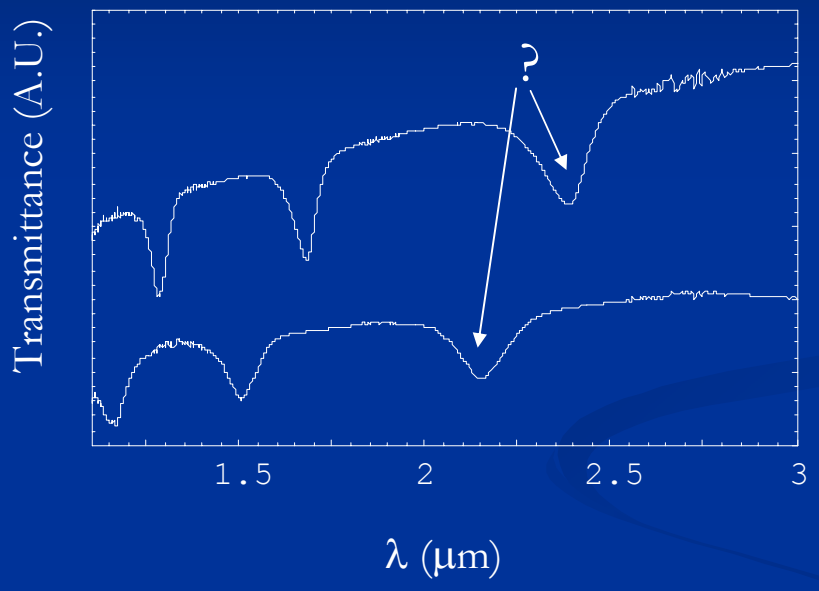
Absorption

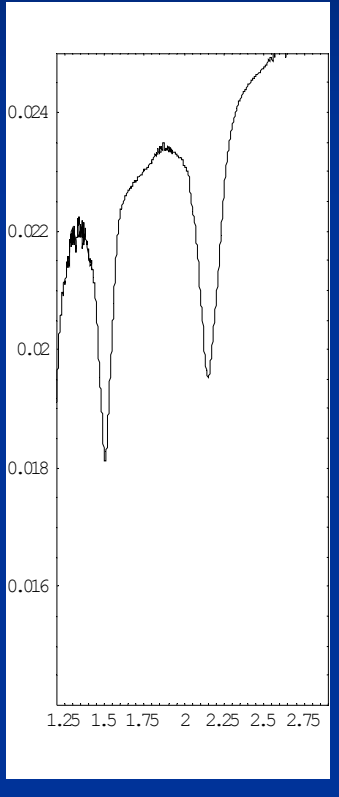


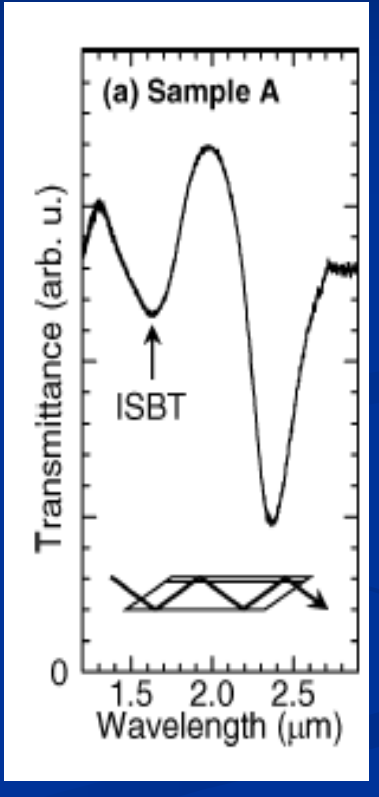
But- longer range absorption



- Peak Shifts with period and has right polarisation for ISBT
- Energy corresponds to calculate $HH_1 - HH_3$ transition energy

Comparison to published data

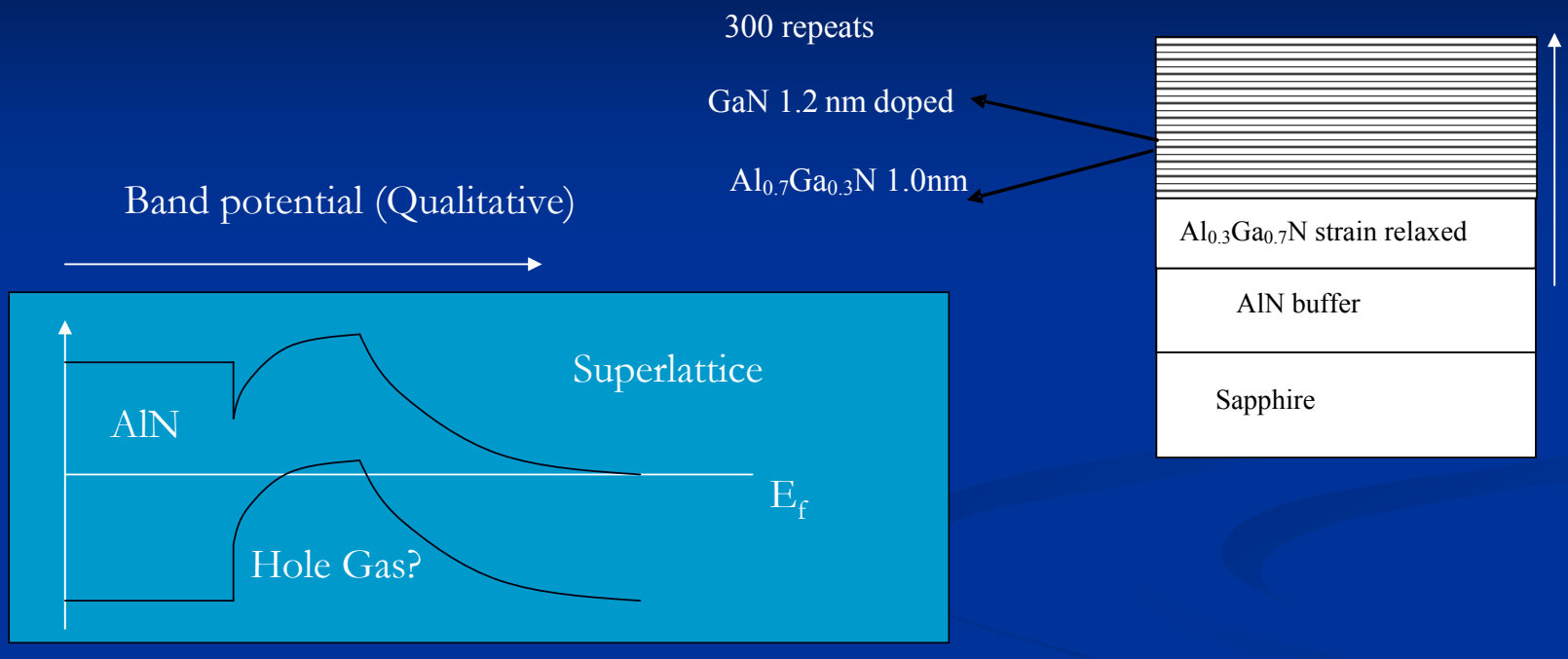




Lizuka et al 2002

Heavily doped AlN/GaN structure on AlN buffer

Sample structure and strain



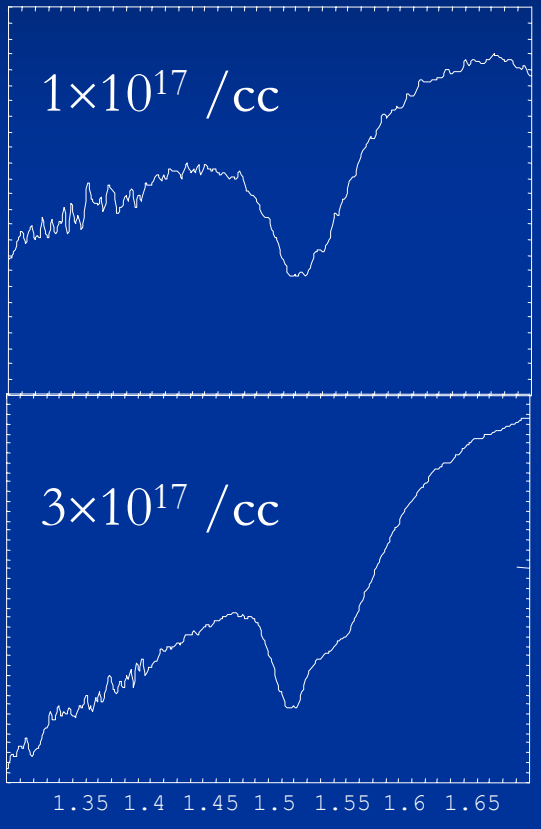
- Previous reports of absorption features due to hole gases in AlGaN grown on AlN

e.g. M. S. Shur, A. D. Bykhovski, and R. Gaska, Solid-State Electronics **44,** 205-210 (2000).

Absorption due to holes

- Strain induced hole gas must be present at base of superlattice stack
- Only HH_1,HH_2 and HH_3transitions in well
- HH_1-HH_2 not observed due to absorption of by Sapphire substrate
- For device control of strain and removal of p-region essential

Effect of doping Density



- broadening due to inhomogeneous process
- probably related to fermi-level variation

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Conclusions

- MOVPE can produce AlGaN/GaN intersubband structures with transitions in the telecoms region of the spectrum.
- The use of MOVPE with AlN on sapphire technology gives superior sample quality and lower linewidths compared to current MBE samples
- Presence of hole gas at sample base indicated by hole ISBTs in absorption

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