The University Of Sheffield.

EEE6212 “Semiconductor Materials” -Assignment

Professor Richard Hogg,
Centre for Nanoscience & Technology, North Campus
Tel 0114 2225168,
Email - r.hogg@shef.ac.uk

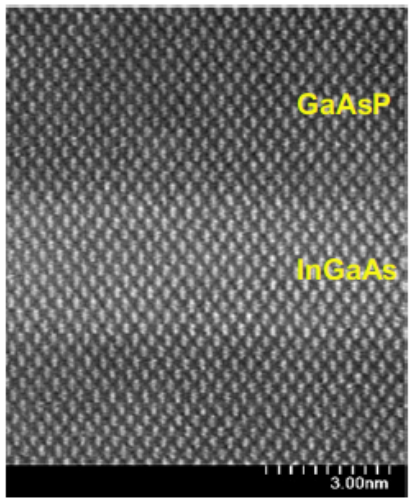
Introduction

- Discuss need for characterisation of epitaxial materials
- Focus on combination of photoluminescence and X-Ray diffraction
- Discuss both
- Introduce samples you will study
- How, where, when

The University Of Sheffield.

Motivation

- Advanced semiconductor structures are realised via epitaxial processes
- Structures have varying alloy compositions, doping, thickness (mono-layer precision)
- Need methods to characterise deposited materials
- In manufacturing – non-destructive characterisation is required
- PL and X-ray diffraction are a complementary set of methods

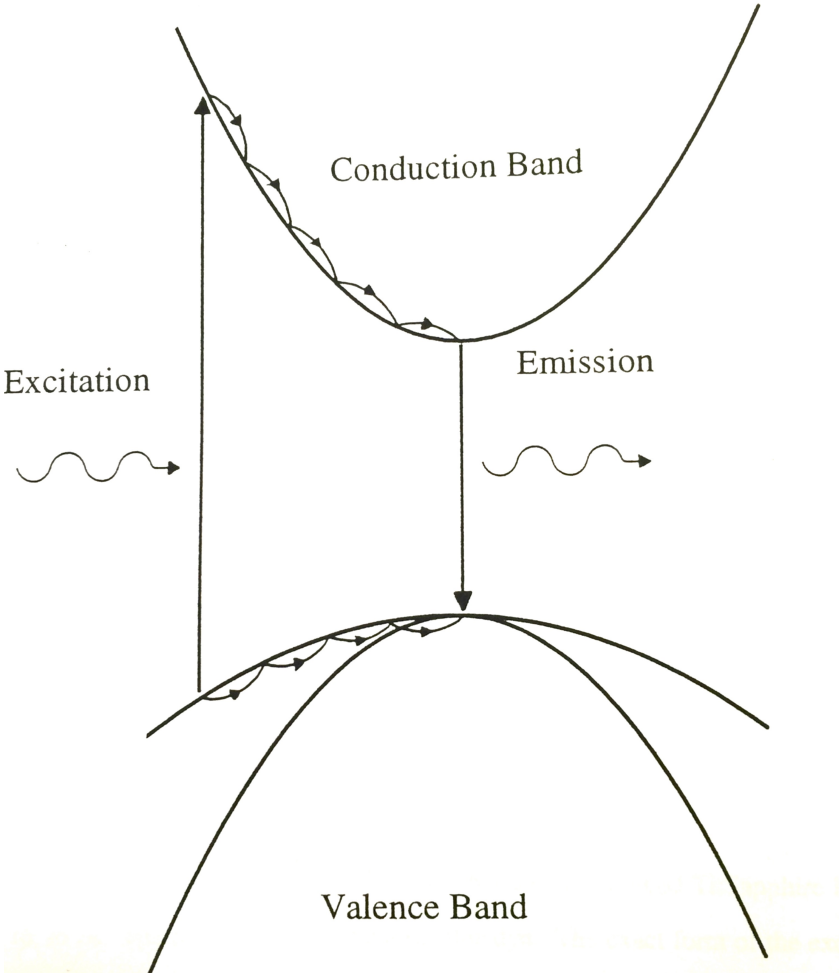


Photoluminescence (PL)

3 step process

Excitation – above band-gap light creates electrons and holes
Relaxation – electron (hole) relaxes to conduction band minimum (valence band maxima)
Emission – the electron and hole recombine through spontaneous emission

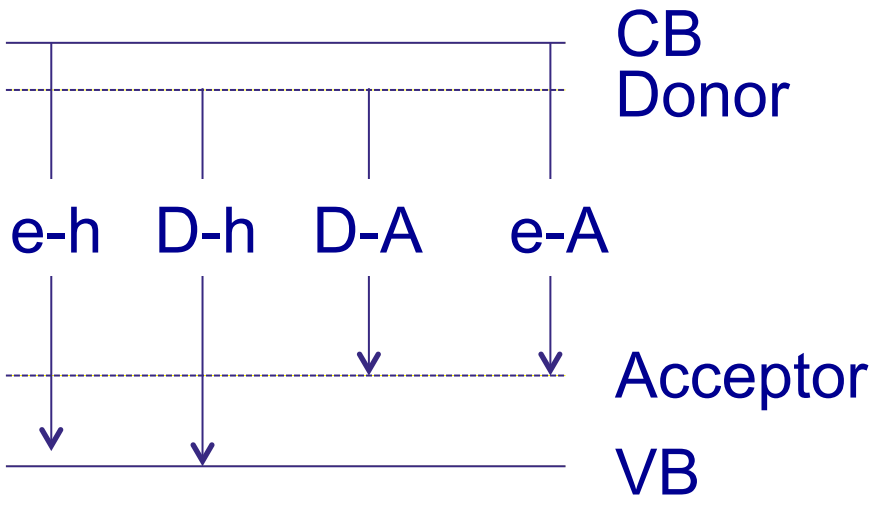
Provides a direct measure of the band-gap (caveats to this over the page!)



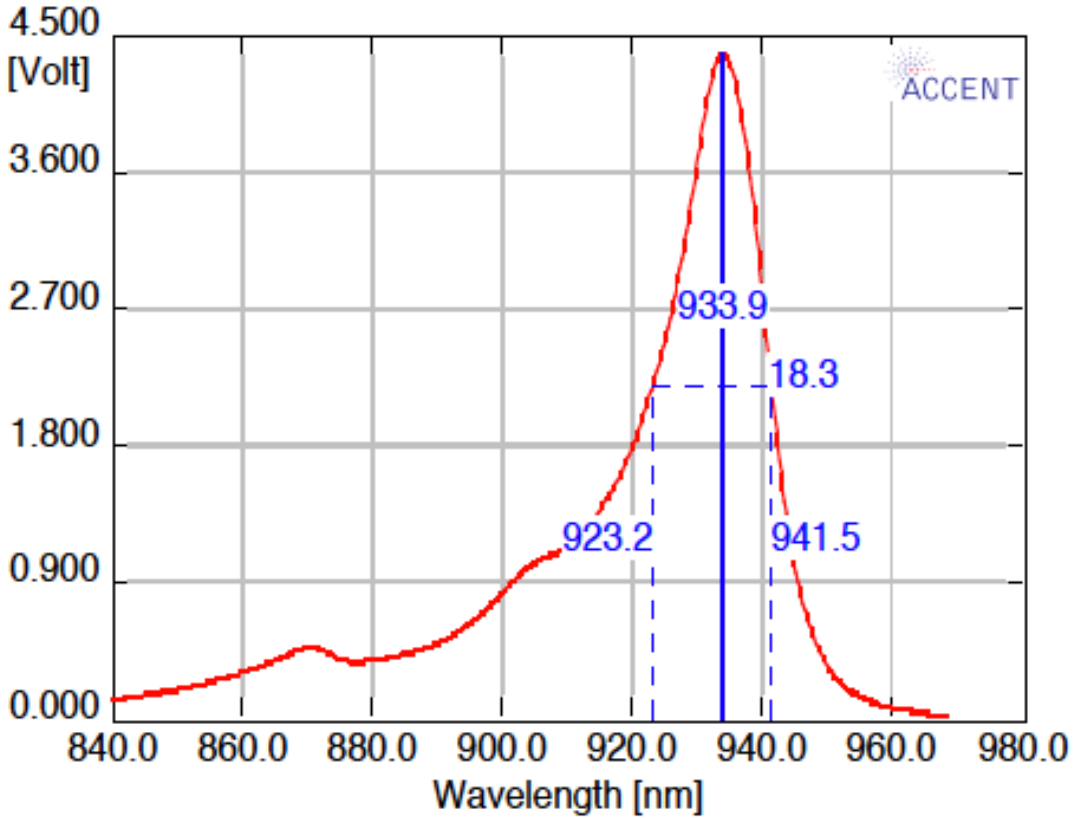
PL – Band-gap Caveats…..

Excitons ? Depending upon the band-gap and the temperature, excitons have a lower energy than the band-gap. At room temperature – not a problem for GaAs, InP.

Donors, Acceptor ?



Room Temperature Line-shape

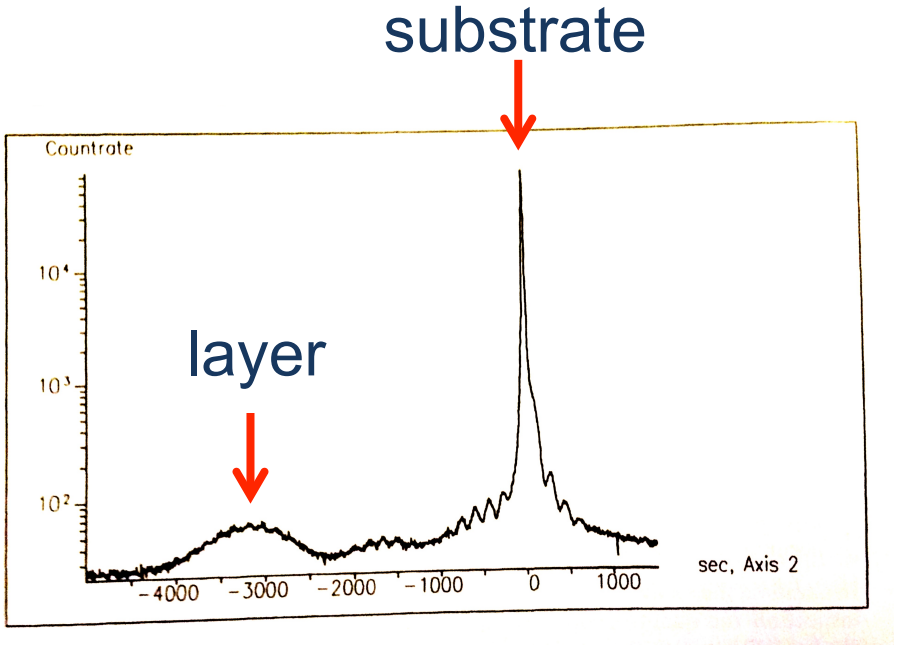


Lineshape is a convolution of Boltzmann Fn and Gaussian (See paper)

Other features from other states (GaAs band-edge, higher order states in QW…)

X-Ray Diffraction – Bulk

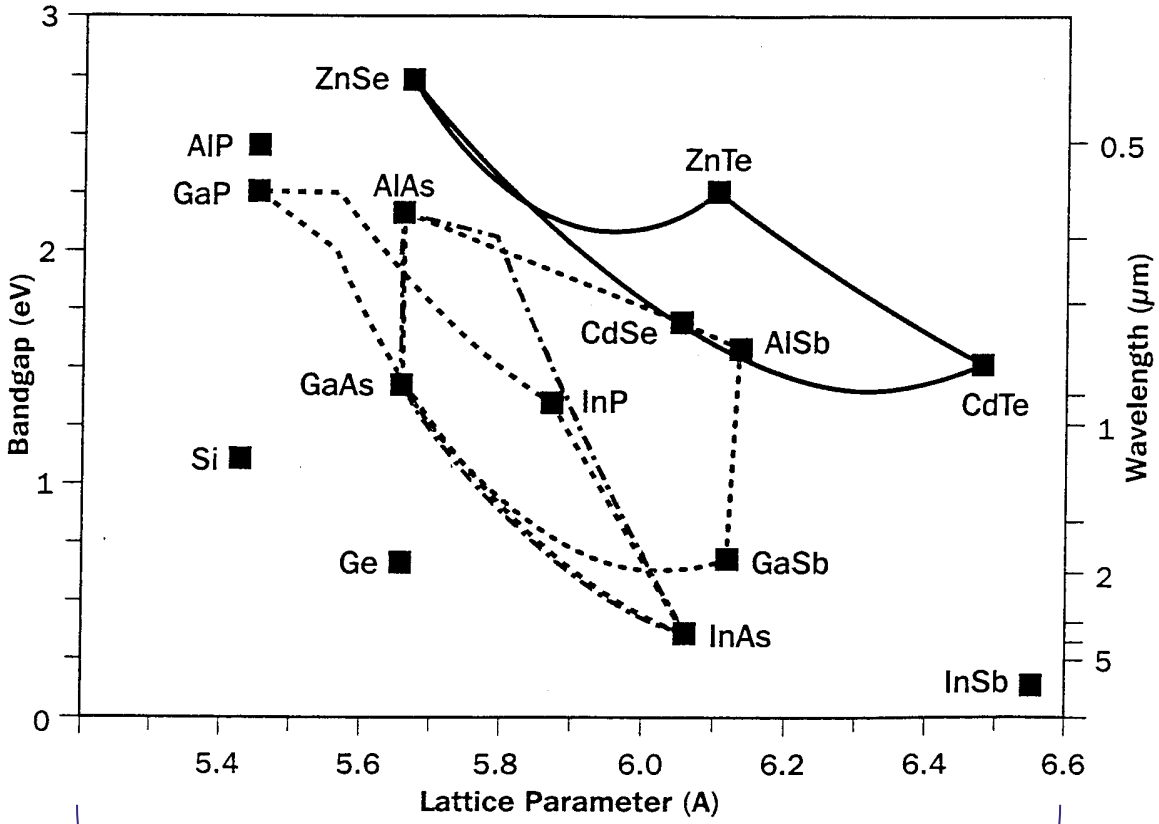
- See previous lecture… XRD tells you many things about the deposited layers
- Critically - provides a measure of the lattice constants in-plane and out-of plane



The University Of Sheffield.

PL and X-Ray - Bulk

PL



X-Ray Diffraction

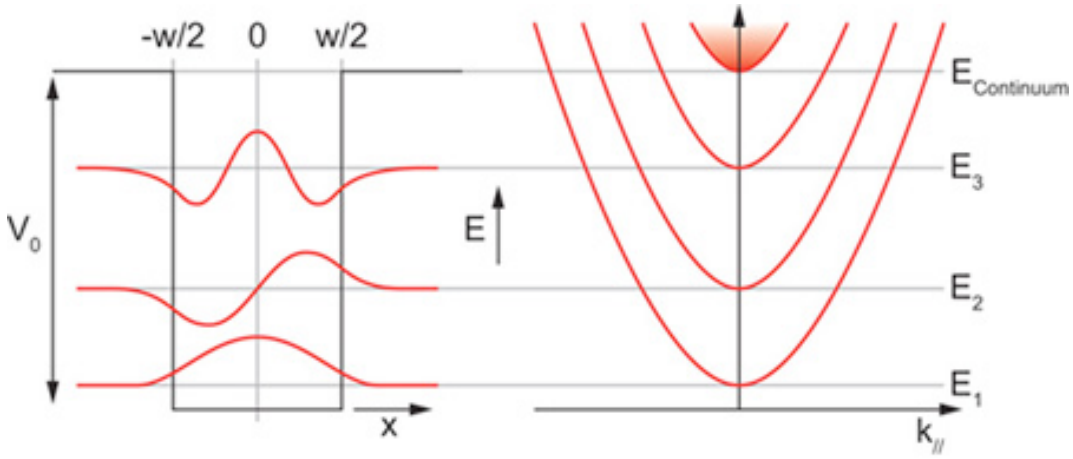
The Quantum Well

(We will do this in more detail later…)

QW - Semiconductor structure which creates a potential on the length scale of the De Broglie wavelength of the electron

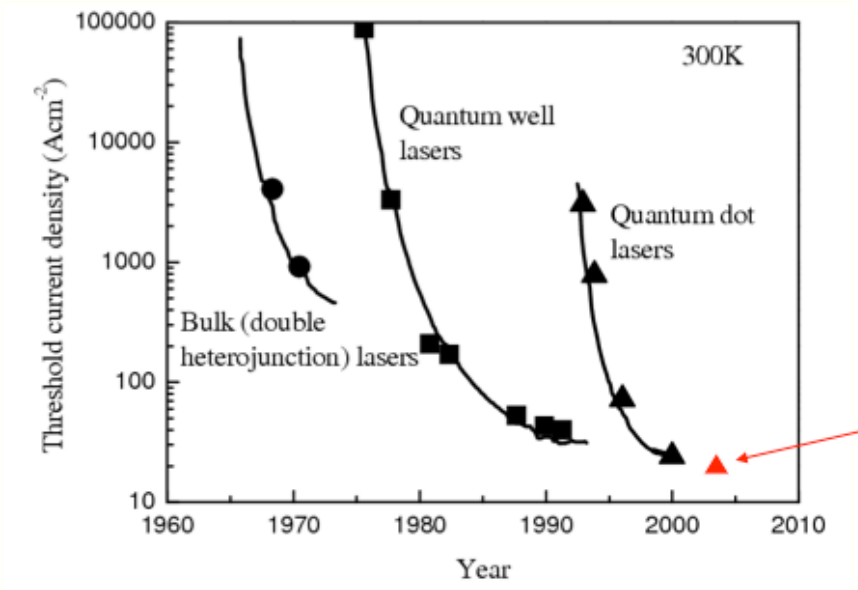
-Lowest energy state no longer from band-edge

-Quantum confinement Energy depends upon depth and width of quantum well



QW – Why care?

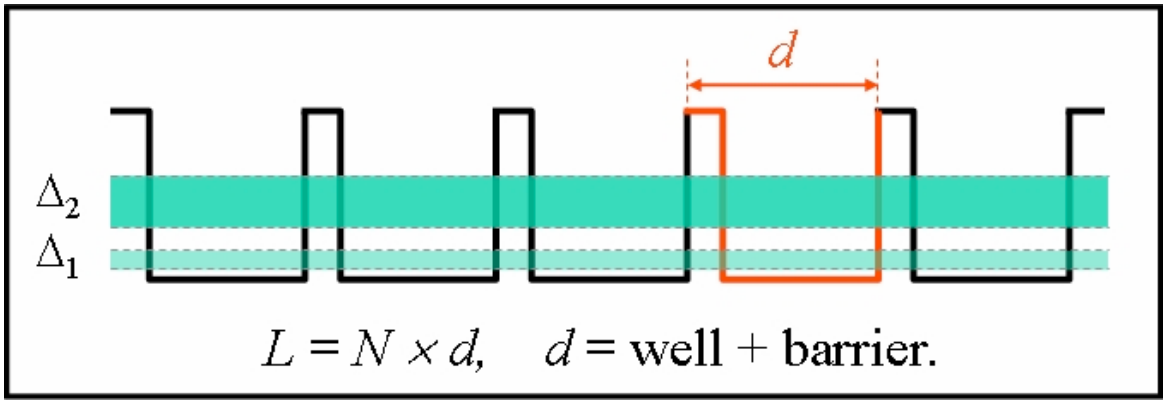
- At the heart of every semiconductor laser
- Many transistors enabled by QWs
- State-of-the-art solar cells…



n.b. The Term “Superlattice”

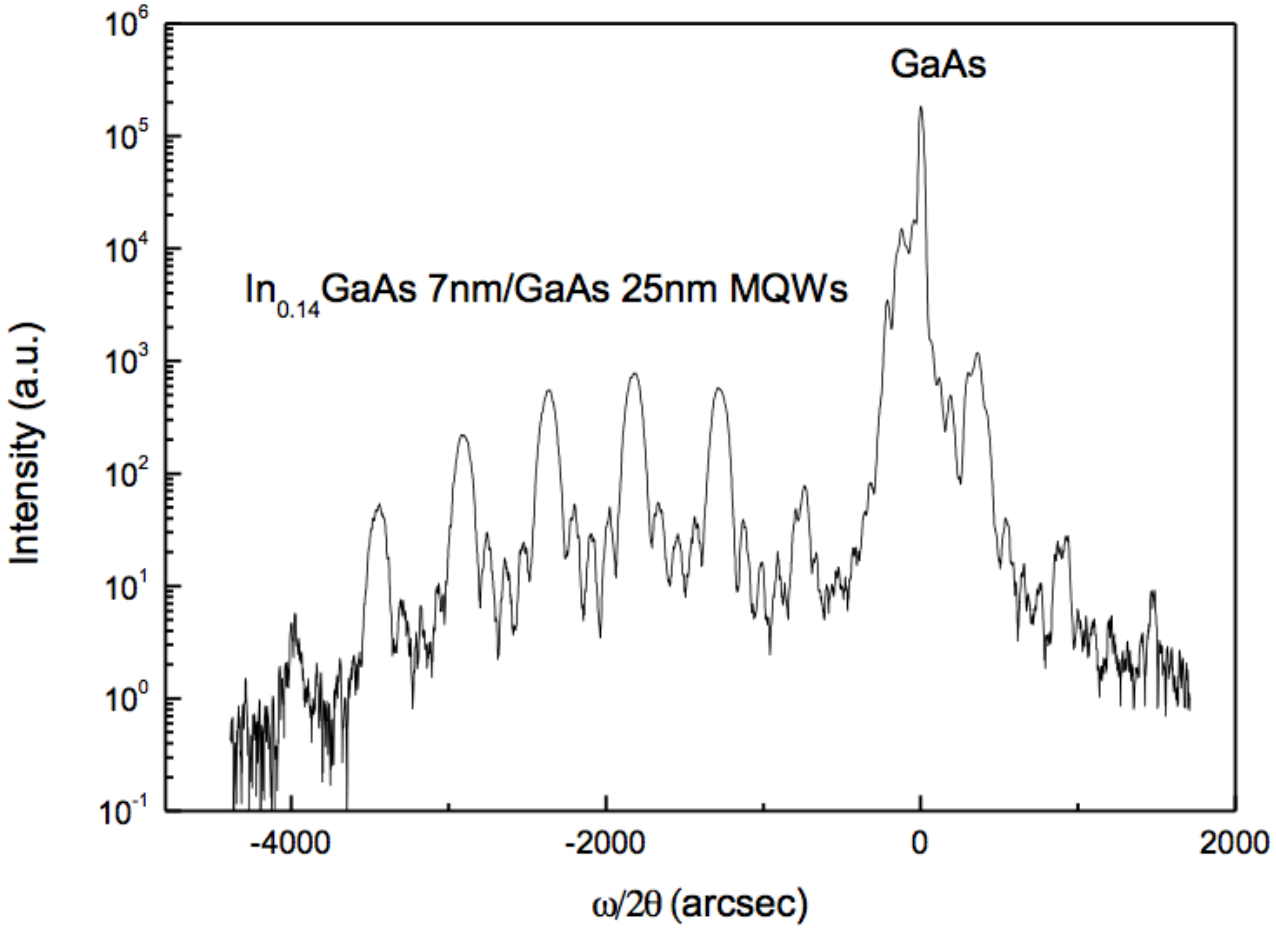
- Crystallography – multiple layers A/B/A/B……

- Quantum mechanics – analogous to a crystal lattice – short period quantum well with



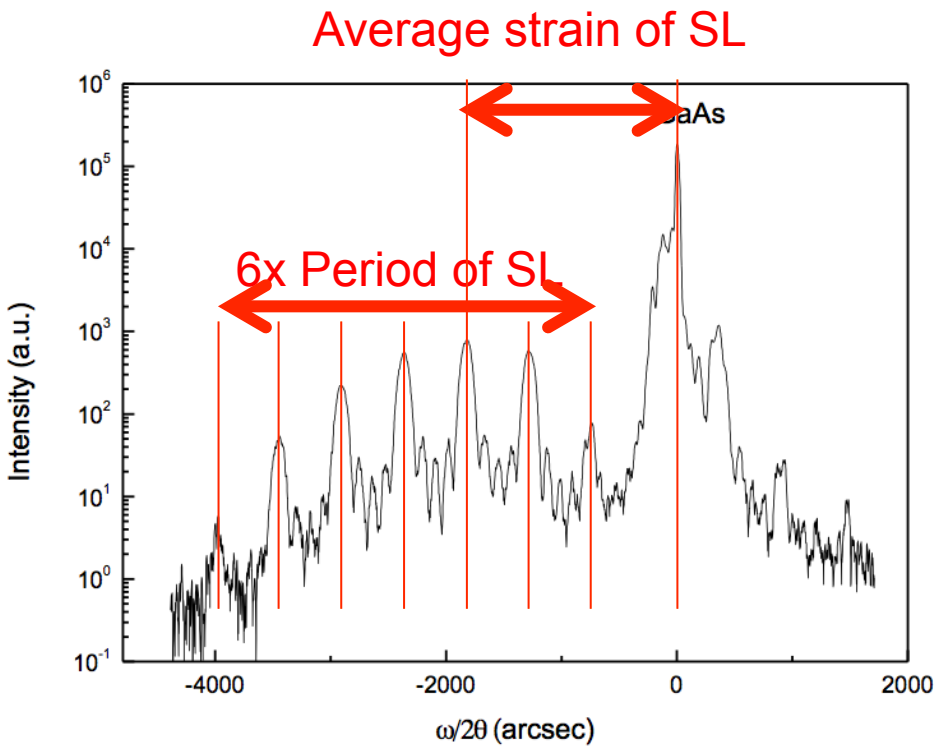
The University Of Sheffield.

Example X-Ray Diffraction



The University Of Sheffield.

Superlattice - X-Ray



Substrate peak

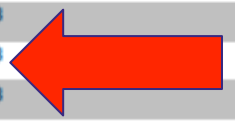
Zero-order peak – addition of Bragg reflections from A and B components of superlattice. Average composition of A + B layers can be obtained by differentiation of Bragg's law.

Satellite peaks –spacing determined by periodicity of superlattice

The University Of Sheffield.

Your Test Samples

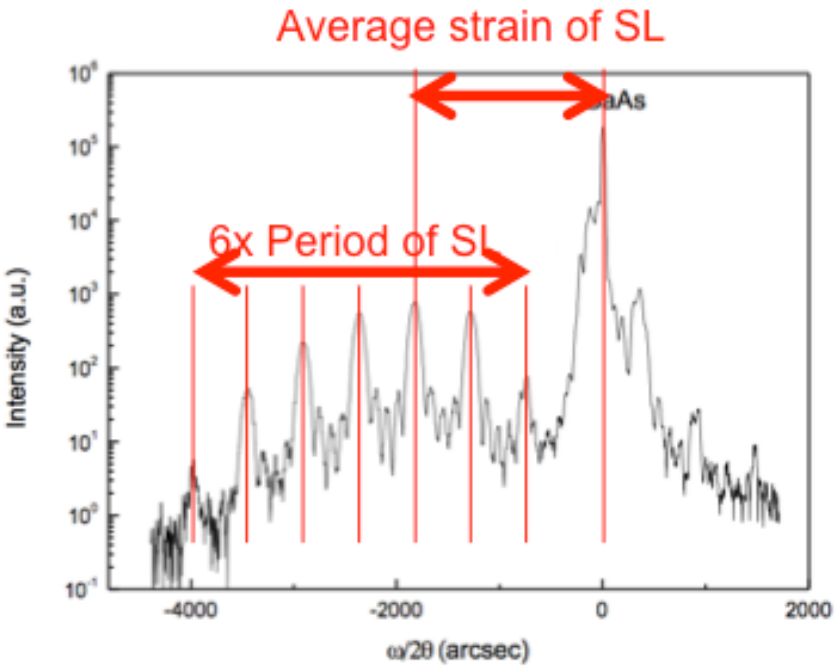
Repeats	Thickness	Thickness tolerance	Material	Material tolerance	Doping type	Doping level	Doping tolerance
1	20.0 nm		GaAs		Undoped	0.0 cm^{-3}	
1	50.0 nm		$Al_{(0.3)}Ga_{(0.7)}As$		Undoped	0.0 cm^{-3}	
1	25.0 nm		GaAs		Undoped	0.0 cm^{-3}	
5	25.0 nm		GaAs		Undoped	0.0 cm^{-3}	
5	8.0 nm		$In_{(0.12)}Ga_{(0.88)}As$		Undoped	0.0 cm^{-3}	
1	50.0 nm		GaAs		Undoped	0.0 cm^{-3}	
1	50.0 nm		$Al_{(0.3)}Ga_{(0.7)}As$		Undoped	0.0	
1	200.0 nm		GaAs		Undoped	0.0	
1	1.0 nm		-		Undoped	0.0	



Various [In], thicknesses

The University Of Sheffield.

Your Experiment…



Substrate peak

Satellite peaks –spacing will change as QW width is varied

Zero-order peak – As period changes, so average strain of SL changes

What You Will Do

- Measure X-Ray diffraction curve for your wafers
  - Deduce the period of your superlattice (assumption that GaAs growth rate doesn't change)
  - Deduce the indium composition of your QW
  - Explore reasons for the shape of the curve
- Measure PL spectrum of your wafers
  - Discuss the form of the spectrum
  - Knowing the indium composition, determine the quantum well width
- Write a report
  - Describe background of PL measurement, X-Ray diffraction, and your measurements

The University Of Sheffield.

When, Where?

- Experiments will take ~2 hours in the Nano-Science Cleanrooms, North Campus

- Monday February 9th – 3PM
- Tuesday February 10th – 3PM
- Friday February 13th – 3PM
- Monday February 16th – 3PM
- Tuesday February 17th – 3PM
- Friday February 20th – 3PM

- DON'T BE LATE….Be in reception at Centre for Nanoscience and Technology at this time….You are advised not to wear a skirt!

How?

- You take the data as a team and have a good long think….
- We will provide a pro-forma template which forms the back-bone of your report and prompt some questions
- You need to describe the experimental procedures, plot graphs (please spend time to do this professionally), process data, draw conclusions and speculate on the interpretation of your data
- The report is worth 25% of the module marks
- Be aware of plagiarism rules and regs…..
- TurnItIn is very efficient…..Don't be a fool….
- ……Good luck!

