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E-Futures

Optical and electrical properties of $GaAs_{1-x}Bi_x/GaAs$ diodes

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Outline

- Introduction
- Results
- Future work
- Summary

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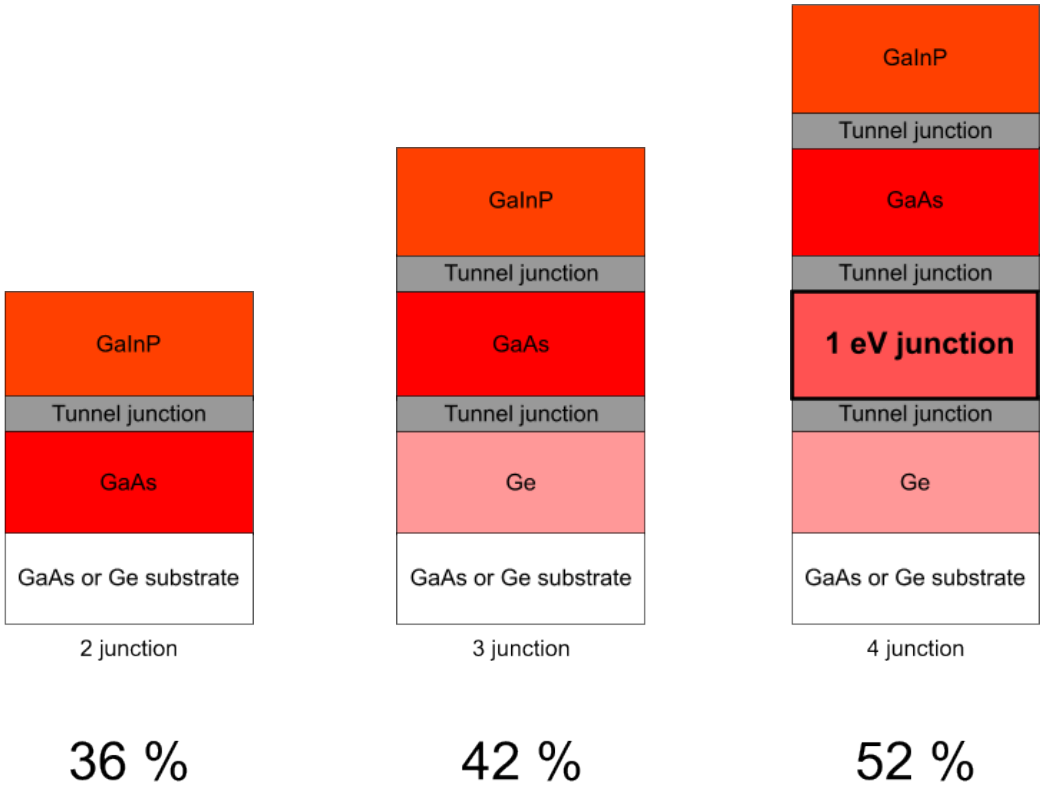
Multi-junction solar cells: the need for a 1 eV band gap material



Predicted efficiencies under AM1.5D spectrum, 500 suns concentration.
Figures adapted from Friedmann et al., http://dx.doi.org/10.1016/S0022-0248(98)00561-2

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InGaAsN

- InGaAsN has been used as a 1eV junction by Solar Century to make a 43.5% efficient MJ solar cell

- However incorporation of N is problematic

- Using N leads to problems such as short diffusion lengths and low depletion widths

- Believed to be caused by defects such as N-N interstitial pairs

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GaAsBiN?

- Growth reported by Huang et al. and Tixier et al.

- Huang et al. determined that GaAsBiN is lattice matched to GaAs for the composition $Ga(N_{0.33}Bi_{0.67})_zAs_{1-z}$

- A 1eV band gap is obtained for z = 0.042, which corresponds to x_N = 0.014 and x_{Bi} = 0.028

- Important to note that N content is **lower** than for InGaAsN with the same band gap (x_N ~ 0.03)

- Reducing N content will improve material quality, however need to determine effect of using Bi instead of In

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GaAsBi with a 1 eV band gap

- No nitrogen source at present therefore looking at just Bi initially

- GaAs p-i-n diode structures containing undoped GaAsBi layers

- Bi content is expected to be around 6%, giving a band gap around 1 eV

- 4 samples with GaAsBi layers, with thicknesses ranging from 50 nm to 350 nm

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Samples grown using MBE-STM system

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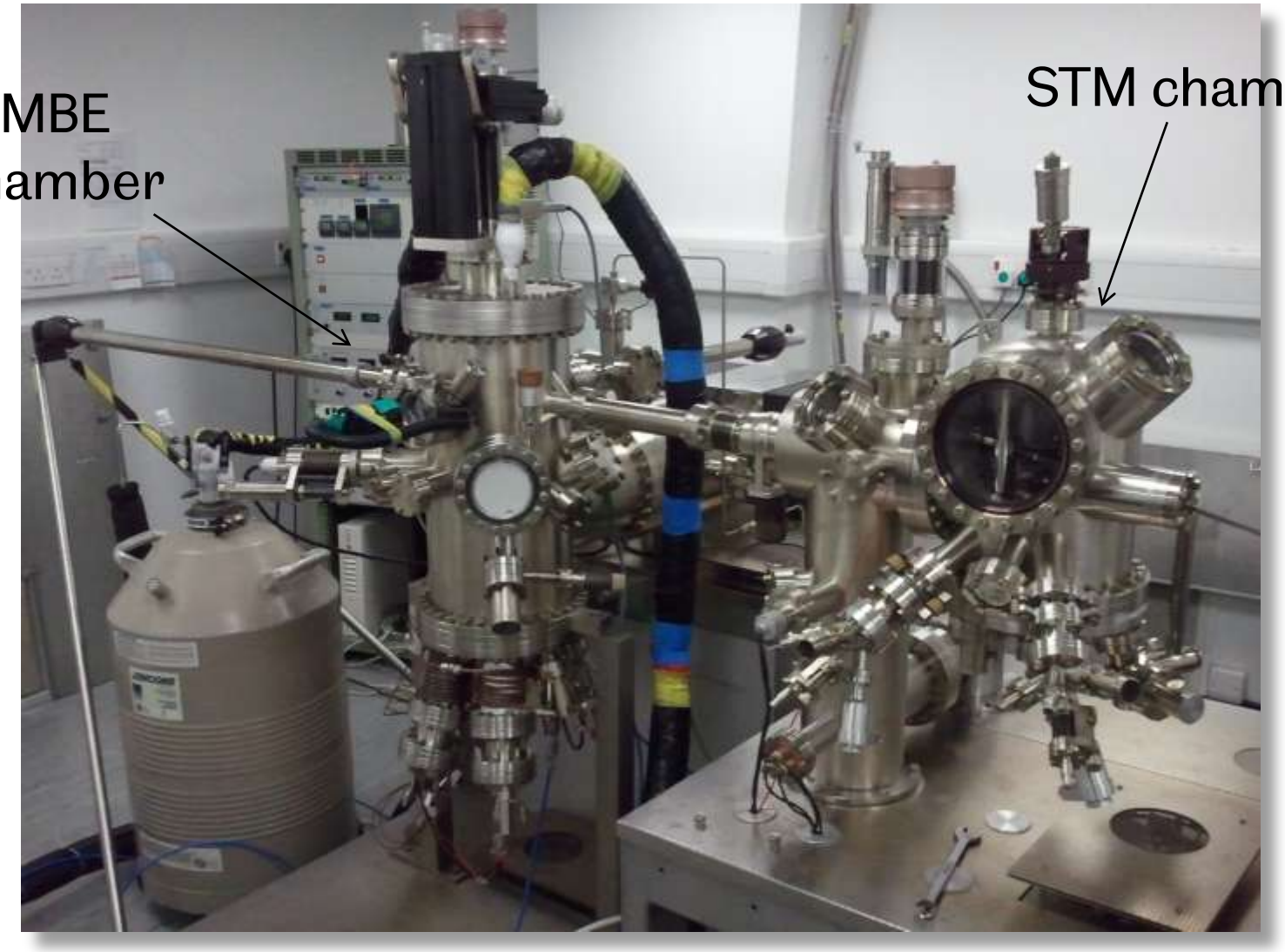

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Sample structure

Material	Type	Doping (cm^{-3})	Thickness (nm)
GaAs cap	p^+	8×10^{18}	600
GaAs spacer	i	N/A	Varied between samples
GaAsBi			
GaAs spacer			
GaAs buffer	n	1×10^{18}	250
GaAs substrate	n^+	4×10^{18}	---

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Sample structure

Sample	GaAsBi layer thickness (nm)	GaAs spacer thickness (nm)
B	50	25
C	100	16
D	200	10
E	350	10

Also grew GaAs control sample “A”, with 400 nm i-region

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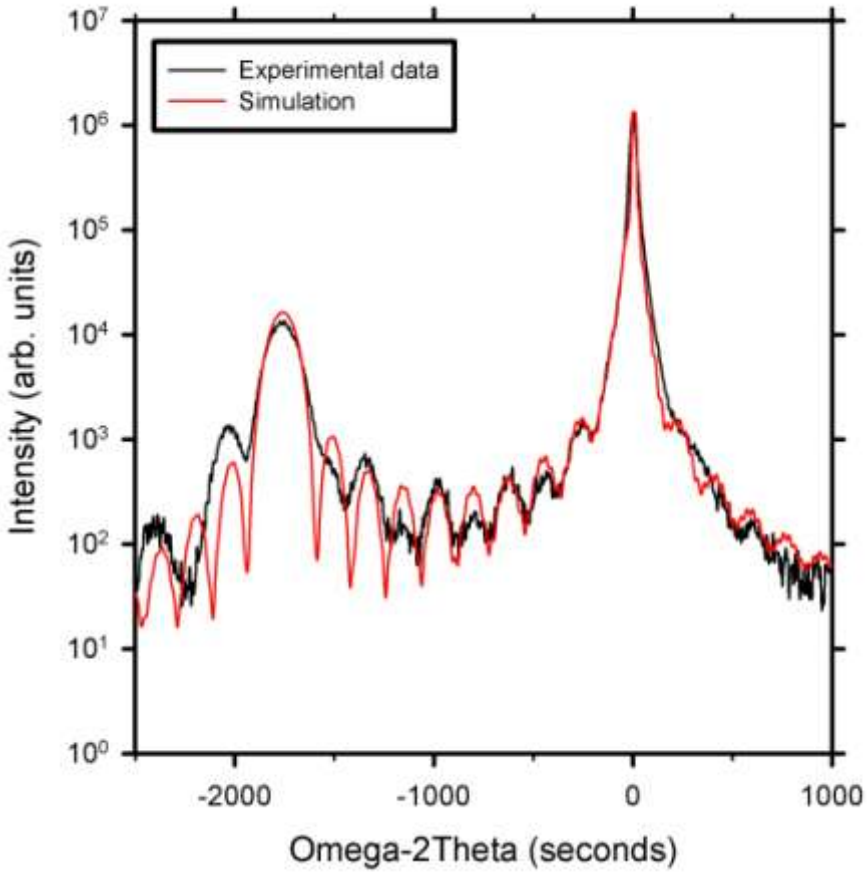
X-ray diffraction

Sample C (100 nm GaAsBi layer)



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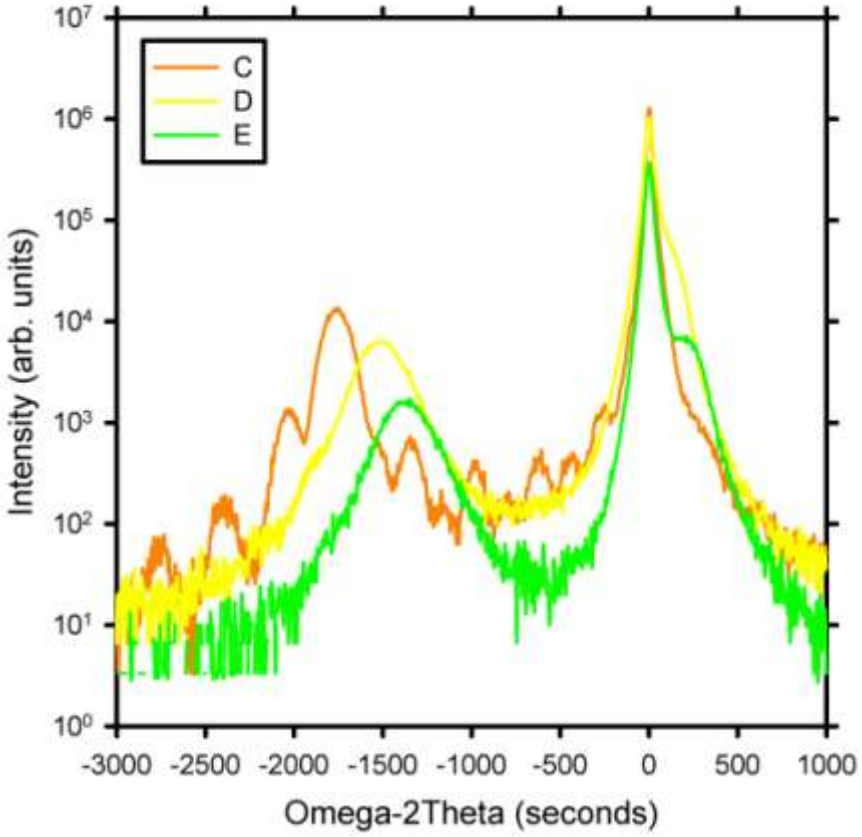
X-ray diffraction



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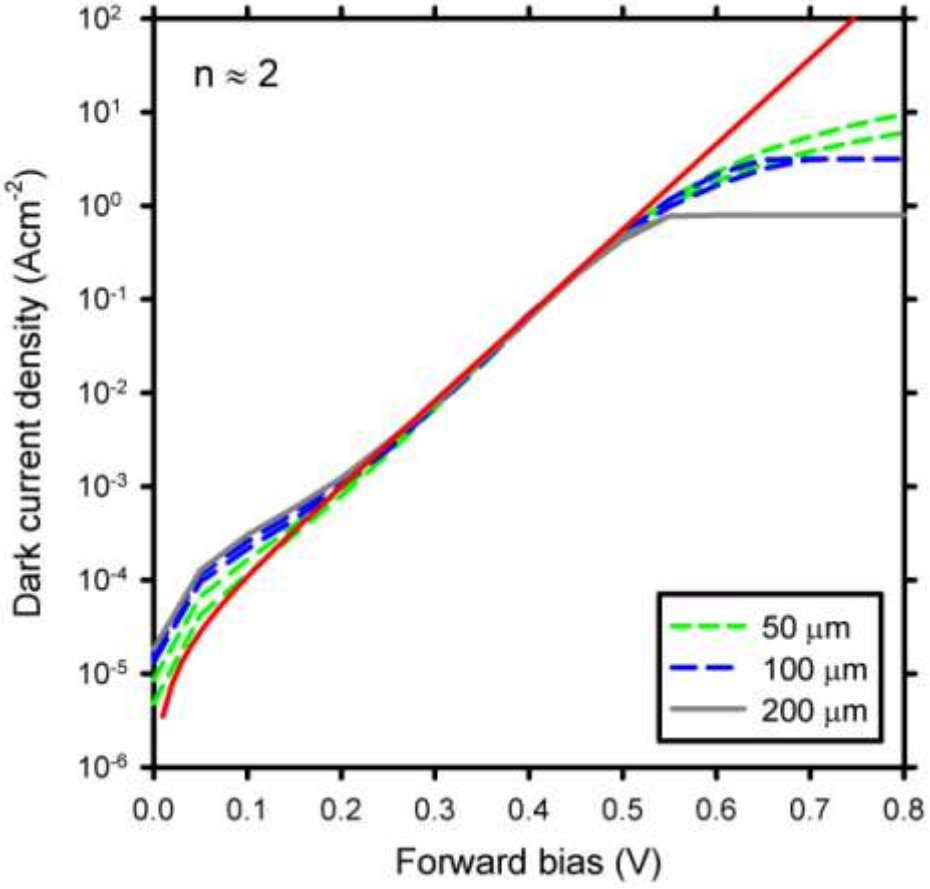
Forward dark J-V

B (50 nm GaAsBi layer)



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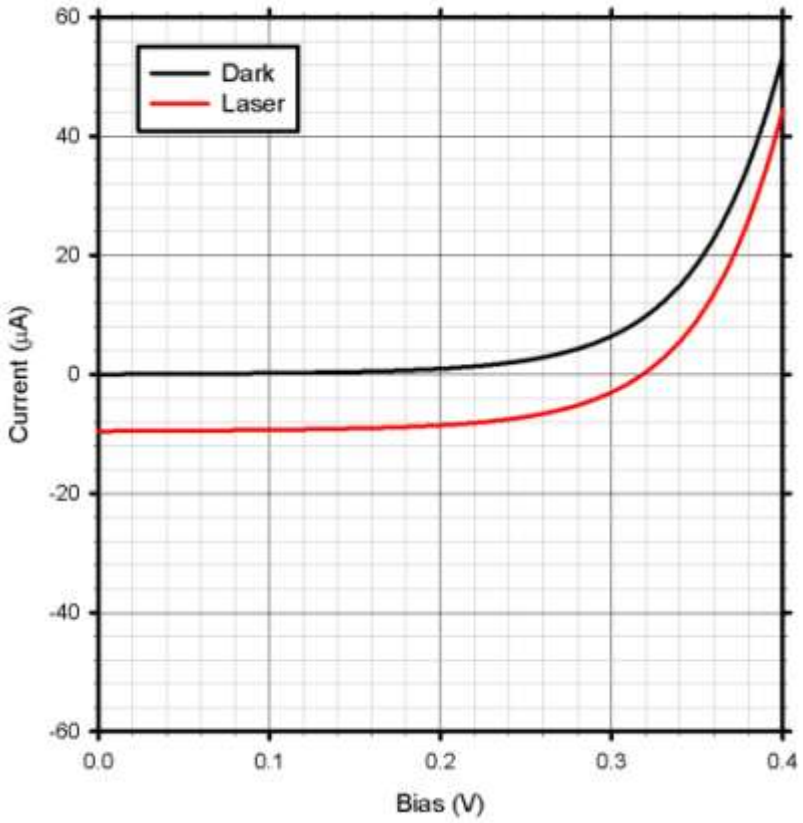
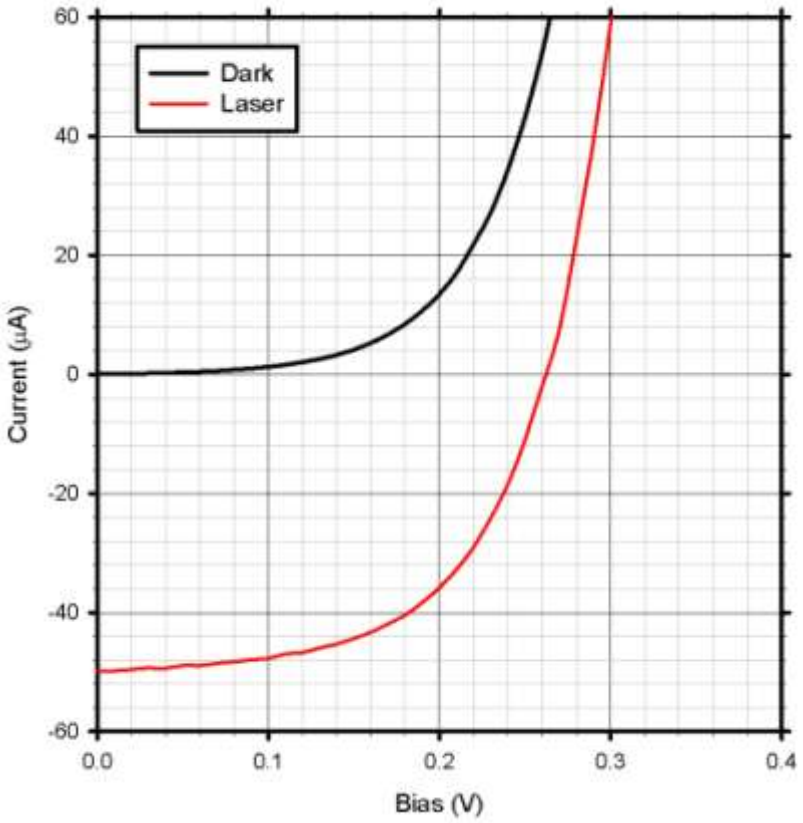
I-V under illumination

B (50 nm GaAsBi layer)



E (350 nm GaAsBi layer)



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I-V under illumination

$$V_{OC} \approx \frac{nkT}{q} \ln\left(\frac{J_L}{J_0}\right)$$

J_L increases due to increased absorption

J_0 increases due to greater number of dislocations

Greater increase of J_0 compared to J_L gives decrease in V_{oc}

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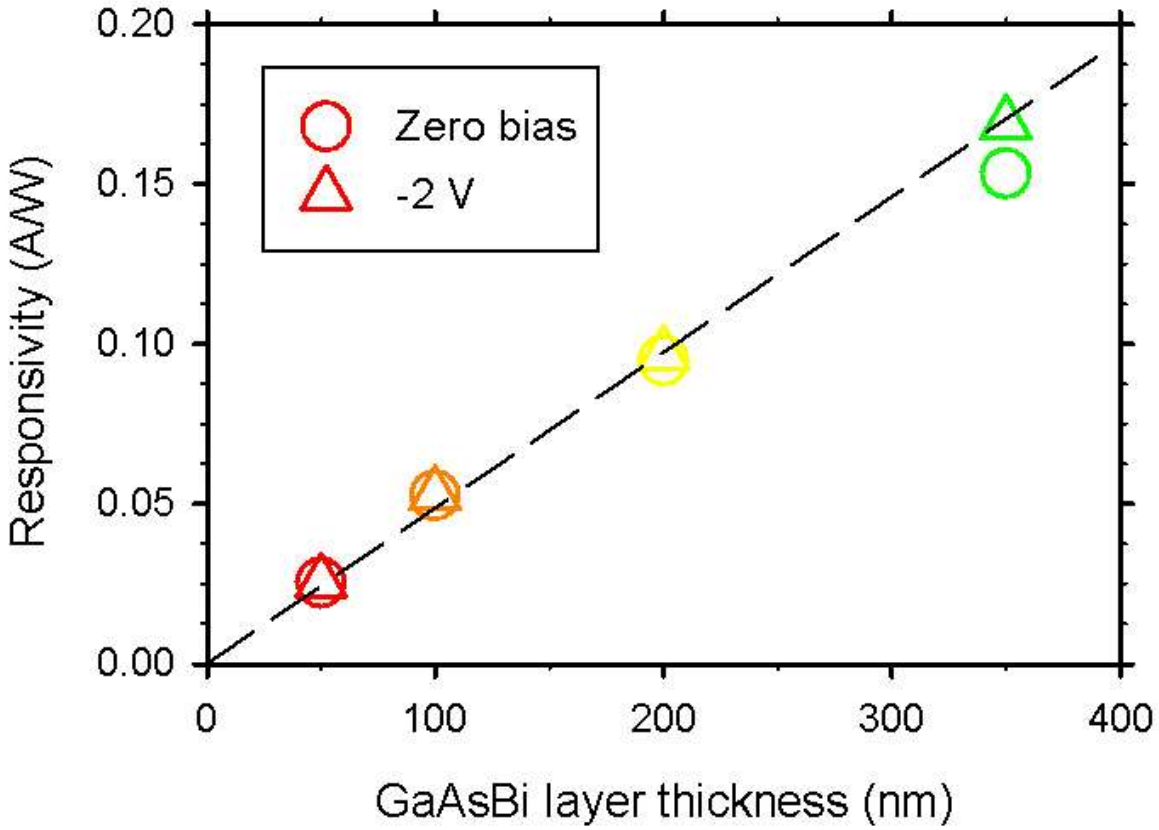
Responsivity at 1064 nm



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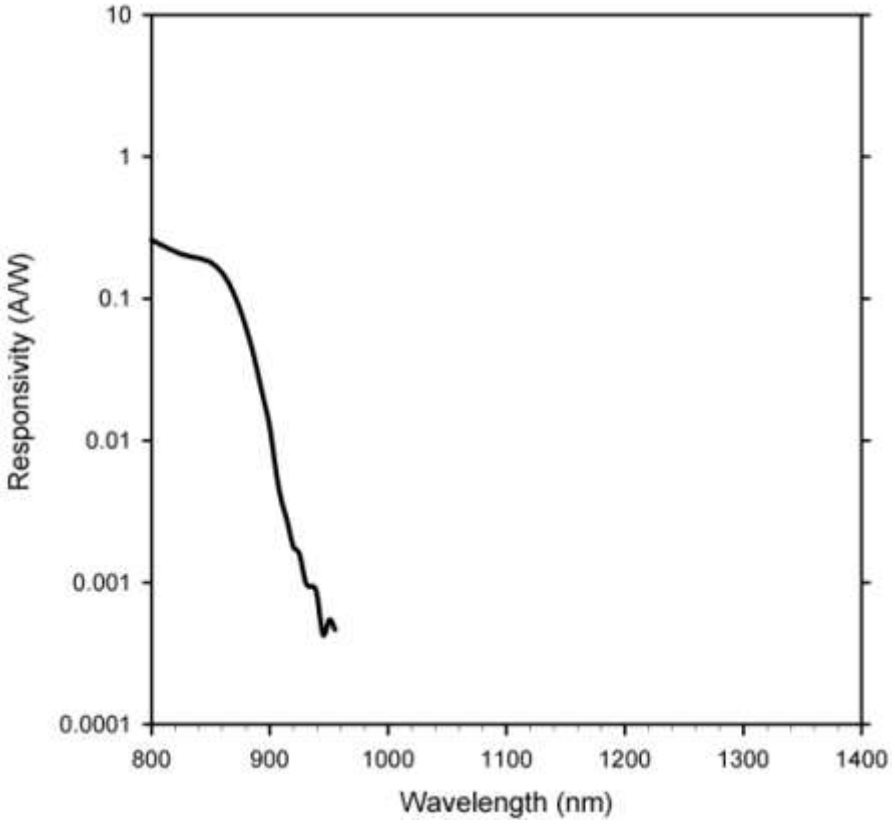
Responsivity as a function of wavelength



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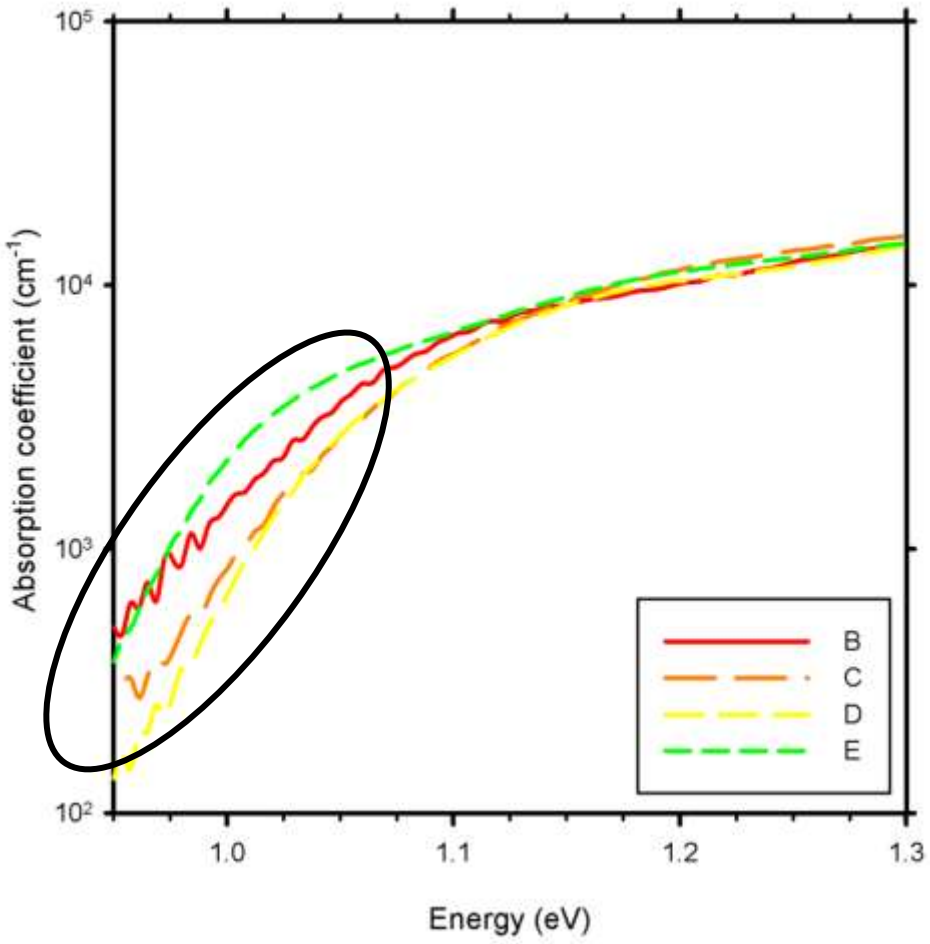
Absorption coefficient

Urbach region



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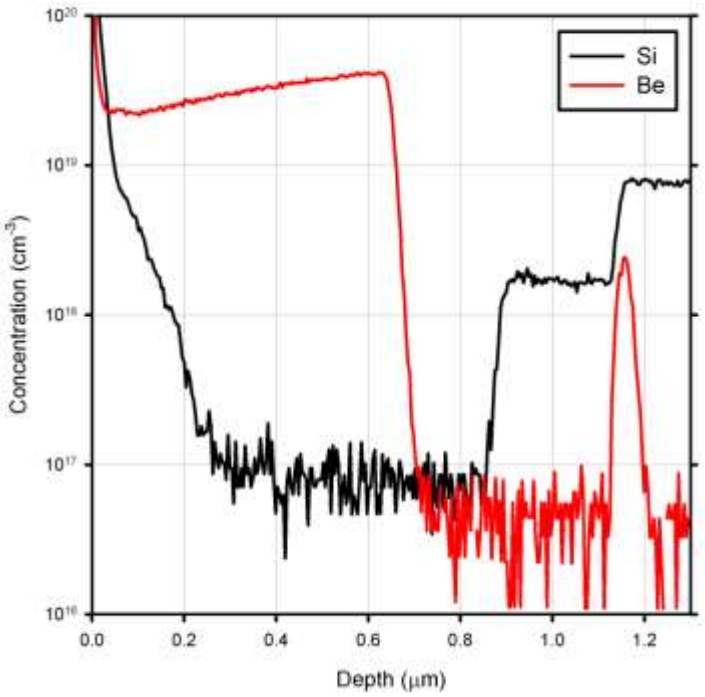
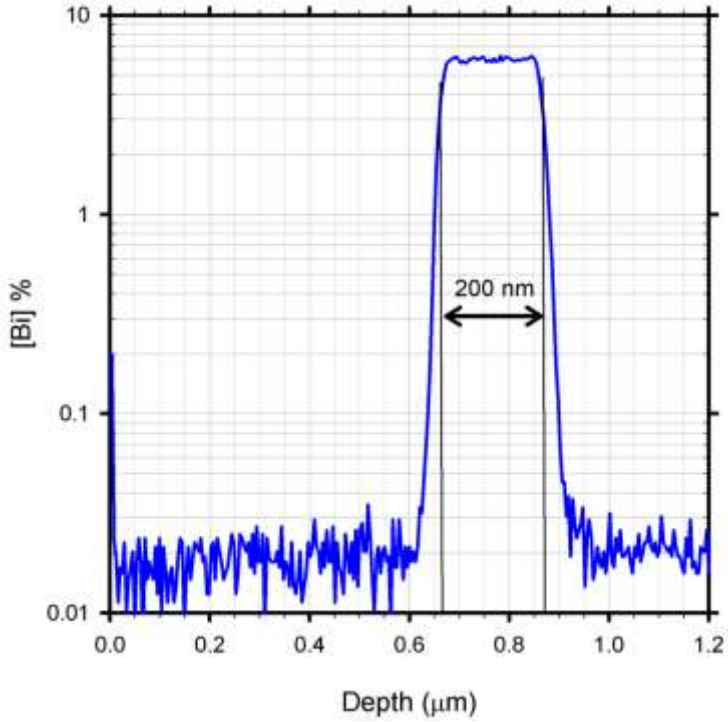
SIMS

Sample D (200 nm GaAsBi layer)





Be concentration higher than expected – non-substitutional Be?
GaAsBi layer thickness roughly as expected
No large variation in Bi content observed

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Future work

- Need to investigate effect GaAsBi has on dark currents

- More structural measurements e.g. SIMS, TEM

- Eventually need to consider lattice matching to GaAs, possibly with addition of N to give GaAsNBi

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Summary

- GaAsBi/GaAs p-i-n diodes have been grown and fabricated

- The presence of the GaAsBi layer extends the photoresponse into the near-IR

- GaAsBi shows increased absorption below the band gap compared to GaAs

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Questions?