Polarization and temperature dependence of photoluminescence from single zincblende and wurtzite InP nanowires

T. B. Hoang, A. Mishra, L. V. Titova, H. E. Jackson and L. M. Smith

University of Cincinnati, Cincinnati, Ohio

J. M. Yarrison-Rice

Miami University, Oxford, Ohio

H. J. Joyce, Q. Gao, H. H. Tan, Y. Kim and C. Jagadish

Australian National University, Canberra, Australia

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Motivation

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- Bulk InP: only Zincblende structure can be grown
- InP nanowires: temperature selective growth
  - 420°C - Zincblende structure
  - ≥480°C - Wurtzite structure
    - Modified energy gap, the electron and hole masses, and recombination selection rules
- We report the polarization and temperature dependence of photoluminescence from single zincblende and wurtzite InP nanowires.

InP nanowire samples

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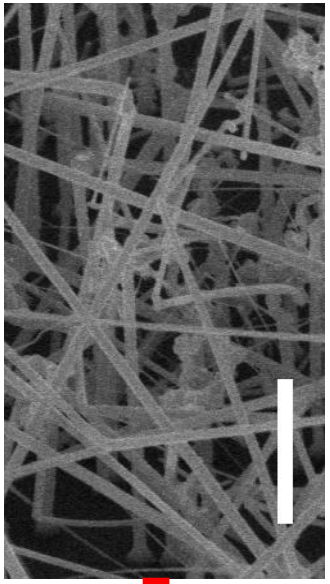
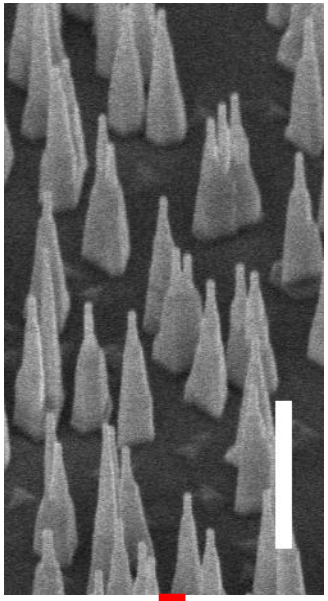
Vapor-Liquid-Solid mechanism

420°C

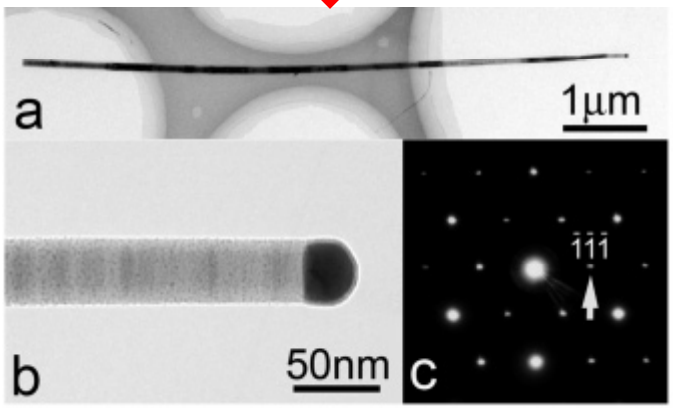


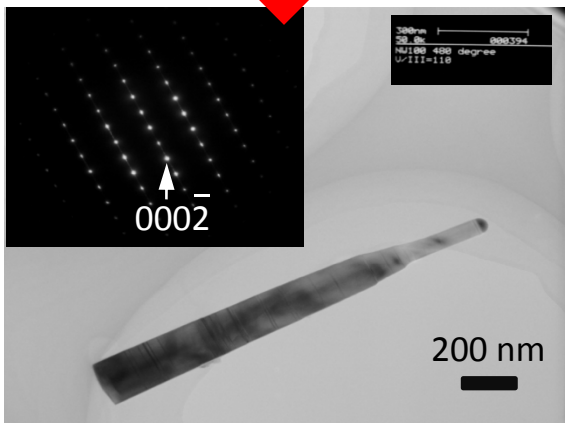
V/III=110

40° tilted FESEM images



480°C





Single nanowire study

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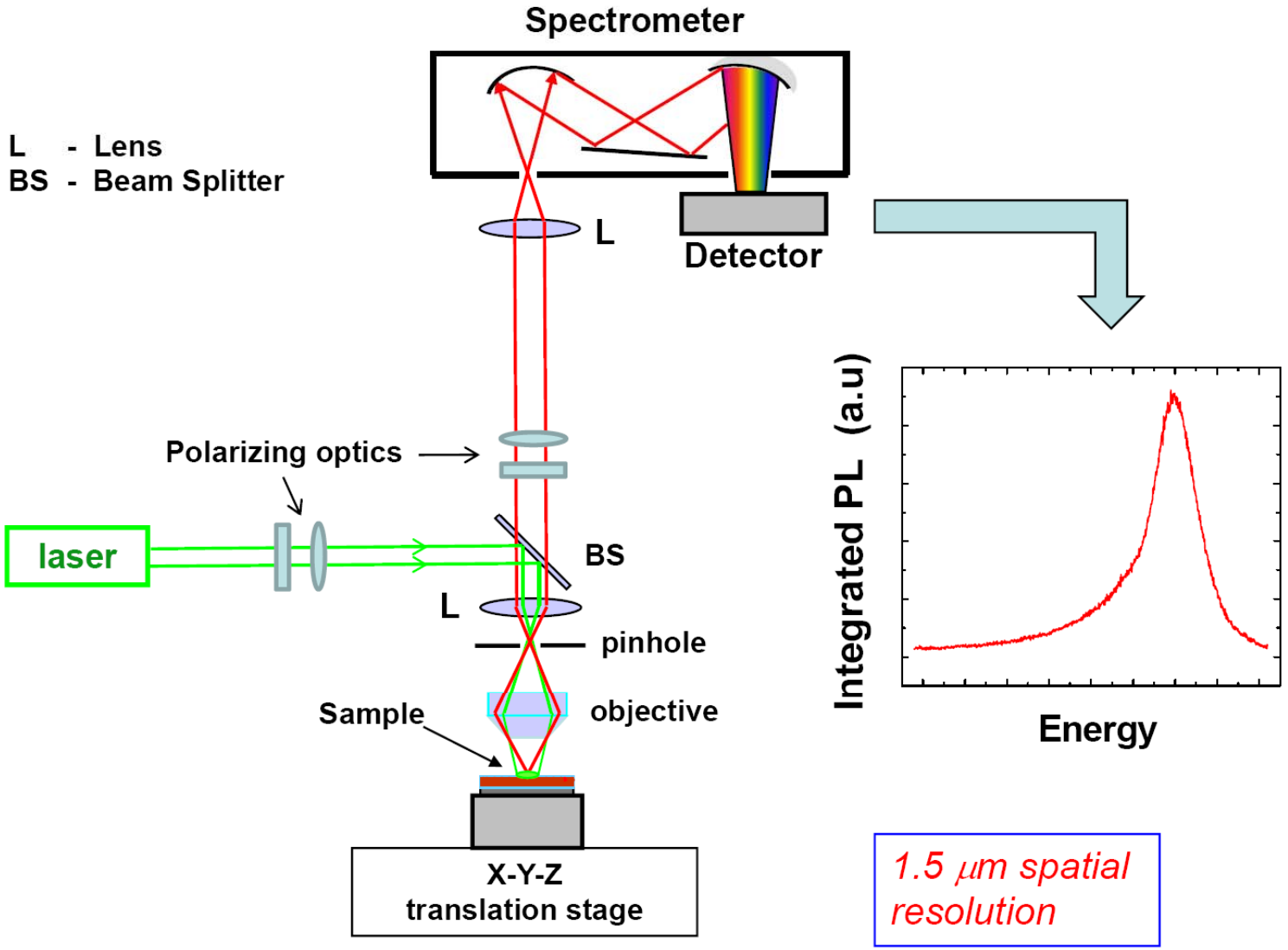
- Nanowires were removed from the growth substrate into solution and deposited onto a silicon substrate

- Single nanowires: diameters ranging from 30 nm to 150 nm, length from 3-10 μm

  - No significant quantum confinement because wire's diameter > Bohr exciton diameter (~10 nm for InP)

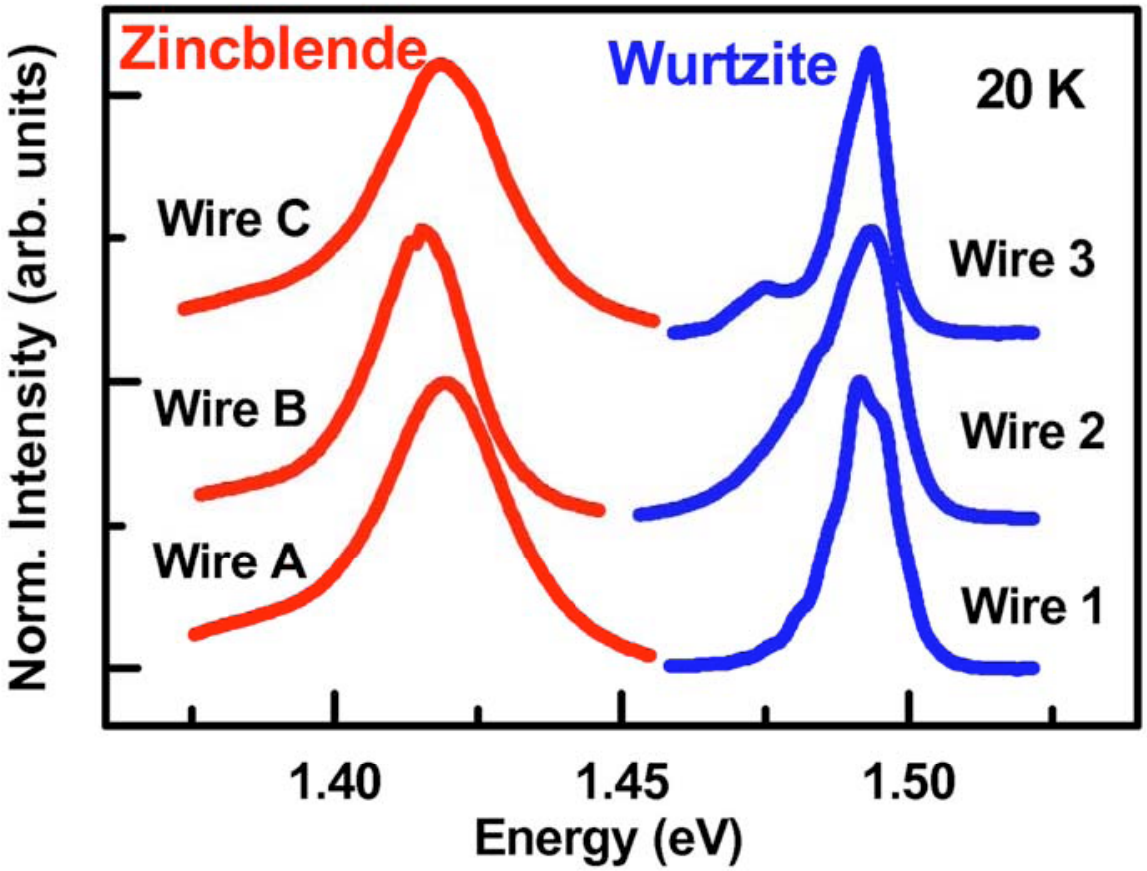
Experimental setup



1.5 μm spatial resolution

Slit-confocal microscopy

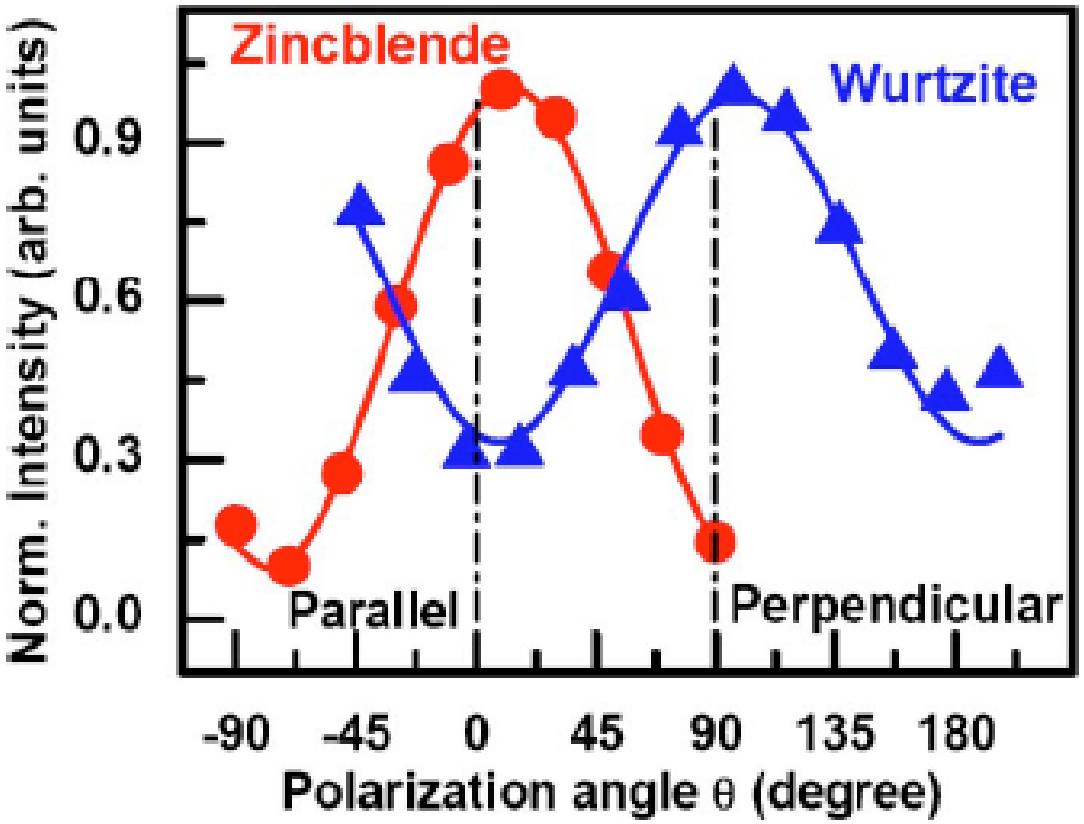
Low temperature PL



Zincblende InP NWs: lower band gap, broader emission band

Wurtzite InP NWs: larger band gap, narrower emission band

Polarization dependent PL



Zincblende (NW A):

Strongly polarized along the wire axis

Wurtzite (NW 1):

Strongly polarized perpendicular to the wire axis

- Laser is circularly polarized
- PL analyzed at angle θ relative to the wire's axis

PL selection rules

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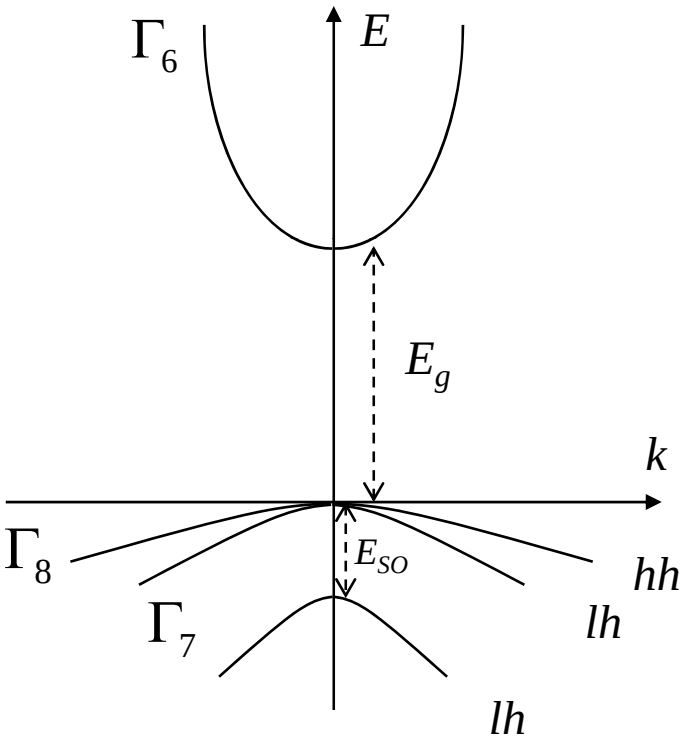
Zincblende

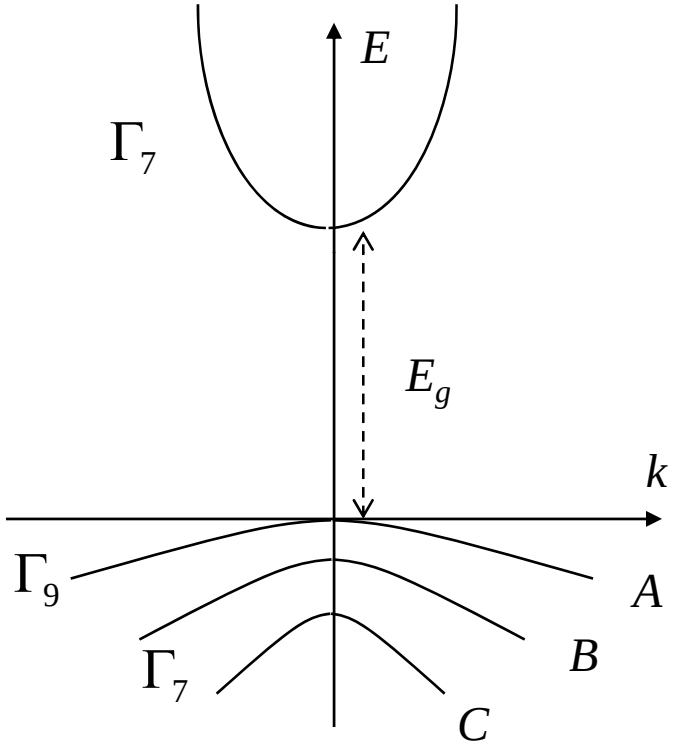


– $\Gamma_6 \rightarrow \Gamma_8$: unpolarized

– Dielectric contrast

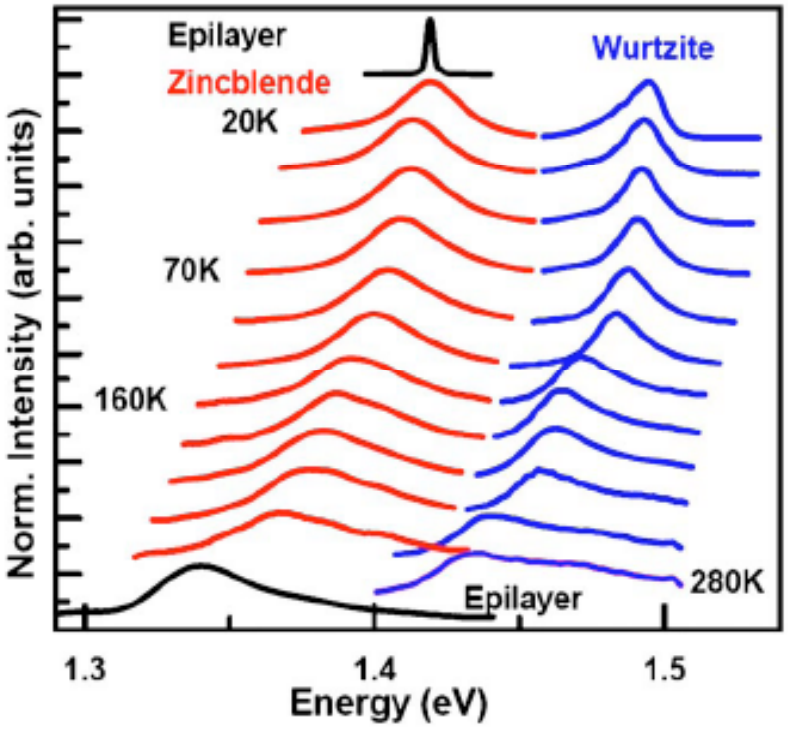
responsible for polarization

Wurtzite



– $\Gamma_7 \rightarrow \Gamma_9$: dipole allowed only if E-field is perpendicular to the c-axis

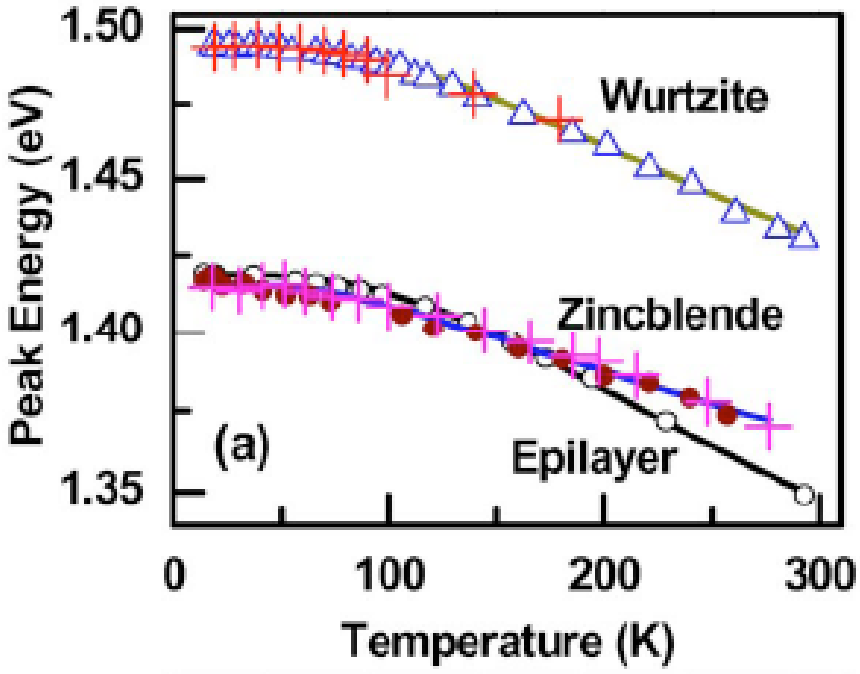
Temperature dependent PL



(PLs normalized for clarity)

PL of both structures persist up to room temperature:

Low non-radiative recombination rate



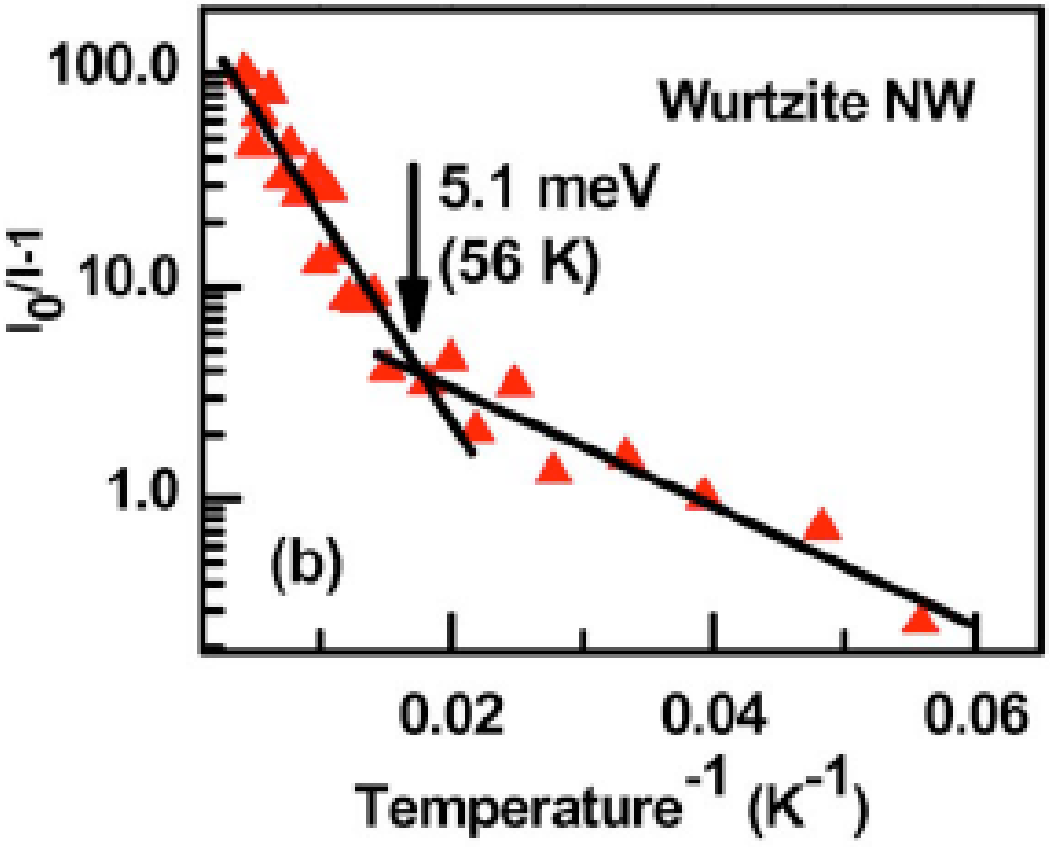
Fit modified Varshni:

$$E = E_0 - \alpha T^4 / (T^3 + \beta)$$

Estimated band gap for Wurt. ~80 meV higher than Zinc.

Exciton binding energy

Plot of $I_0/I-1$ vs. 1/T:



Wurtzite NW:

15-50K: exciton binding energy ~5.1 meV

- **Same masses of electron and hole as in zincblende**

Above 56K: electron-hole plasma emission

*(APL **91** 263104, 2007)*

Summary

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- **InP nanowire:**
  - 420°C – Zincblende
  - 480°C – Wurtzite
- **Single nanowire study**
  - **PL polarization**
    - Zincblende: polarized a long the nanowire axis – dielectric contrast
    - Wurtzite: polarized perpendicular to the c-axis - dipole selection rule
  - **Temperature dependent PL**
    - Both Zincblende and Wurtzite nanowire structures PL follow the band gap of InP epilayer
    - Wurtzite: exciton binding energy ~5.1 meV suggest same masses of electron and hole as in Zincblende