Imaging and optical properties of single core-shell GaAs-AlGaAs nanowires

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Motivation

- we study electronic structure and optical properties of single core-shell GaAs-AlGaAs nanowires

  bare GaAs nanowires: low quantum efficiency due to nonradiative surface recombination

- core-shell GaAs-AlGaAs nanowires have much higher quantum efficiency
Sample growth

Grown by Vapor-Liquid-Solid technique

core:

\[ \text{single-source molecular precursor} \rightarrow \text{nanocluster} \rightarrow \text{nanowire} \]

450° C

shell:

GaAs

Au catalysts

core GaAs

shell AlGaAs

630° C

Single nanowire studies

- Nanowires were removed from the growth substrate into solution and deposited onto a silicon substrate.
- A single nanowire:
  - ~80nm in diameter, ~5-8 µm long

- Wire’s diameter > Bohr exciton diameter
  => expect no quantum confinement
Experimental setup

Ar+/ Ti:Saphire lasers

Spectrometer

L - Lens
BS - Beam Splitter

X-Y-Z translation stage

2D CCD image

PL intensity (a. u.)

Emission energy

Sample
Low-T PL imaging

2D CCD image (spatial vs. emission) shows PL emission along the wire.

shows same emission spectra along the wire

Polarization studies

Polarization studies involve the investigation of how light intensity changes with the direction of light polarization. In this context, the diagram illustrates the setup for studying polarization, where the laser, polarizer, sample, and analyzer are key components.

- **Polarizer**: $\pi_{\theta}$
- **Analyzer**: $\sigma^{+}$

PL emission is strongly polarized parallel to the wire, and is strongly enhanced when the laser excitation is polarized parallel to the wire.

Mathematically, the relationship between the laser polarization angle $\theta$, the polarizer, and the analyzer is represented by:

- For polarizer $\pi_{\theta}$ and analyzer $\sigma^{+}$:
  - Polarizer direction: $\pi_{\theta}$
  - Analyzer direction: $\sigma^{+}$
- For polarizer $\sigma^{+}$ and analyzer $\pi_{\theta}$:
  - Polarizer direction: $\sigma^{+}$
  - Analyzer direction: $\pi_{\theta}$
Resonant excitation

Tune excitation energy, $E_{\text{Laser}}$, record PL intensity.

Resonances at ~74 meV and 150 meV above free exciton energy.

- 1st LO
- 2nd LO

Resonances:
- $h\omega_{\text{excitation}}$
- $h\omega_{\text{emission}}$
Conclusions

- core-shell GaAs-AlGaAs nanowires display strong PL emission (non-radiative surface recombination is suppressed)

- PL emission is *strongly enhanced* when the laser excitation is polarized parallel to the wire, and is *strongly polarized* parallel to the wire

- striking excitation resonances at ~74 meV and ~150 meV above the PL emission line
  - 74 meV: 2LO resonance - phonon-assisted absorption (GaAs)
  - 150 meV: LO resonance of GaAs (higher order) or AlGaAs
Dove Prism (DP) can be used to rotate image of a nanowire