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Single Mode GaN nanowire lasers

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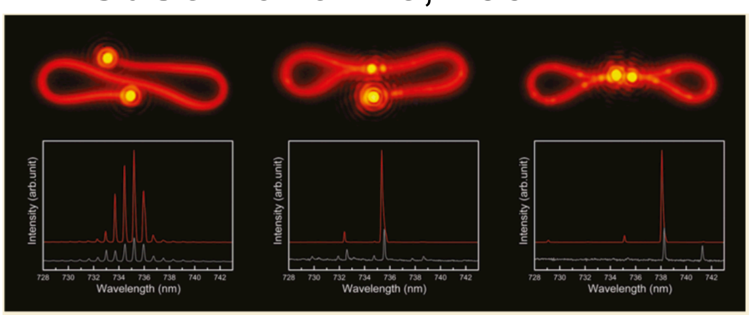
Outline

- Why single mode GaN nanowire laser? State of Art?
- Experimental:
  - Materials: GaN nanowire by “bottom up” technique
  - Measurement: uPL set up
- Strategy 1 :geometry control and mode competition
- Strategy 2 :coupled nanowire pair/Vernier effect
- Summary

Why single mode GaN nanowire laser? State of Art?

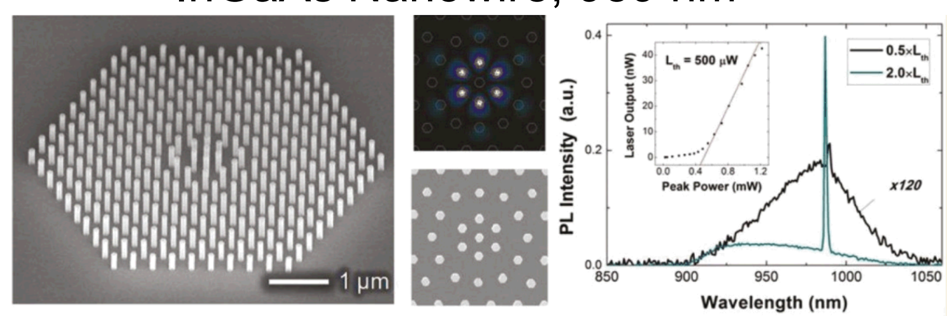
- High Beam Quality, interference-free.
- Desired for imaging, reading, and writing.
- A few reports (CdSe and InGaAs) on single mode nanowire laser (IR range).
- Lack of detailed research on GaN single mode nanowire (UV range).

CdSe Nanowire, 735 nm



Nano Lett., 2011, 11 (3), 1122

InGaAs Nanowire, 989 nm

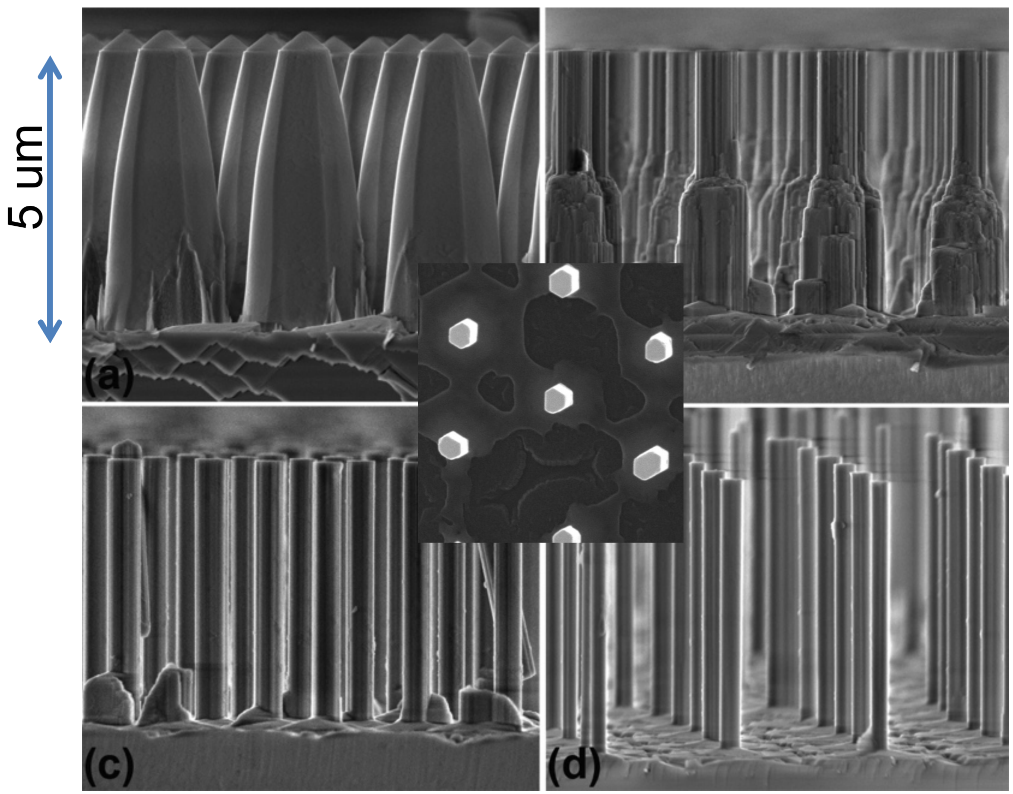


Nano Lett., 2011, 11 (12), 5387

2-step nanowire fabrication process

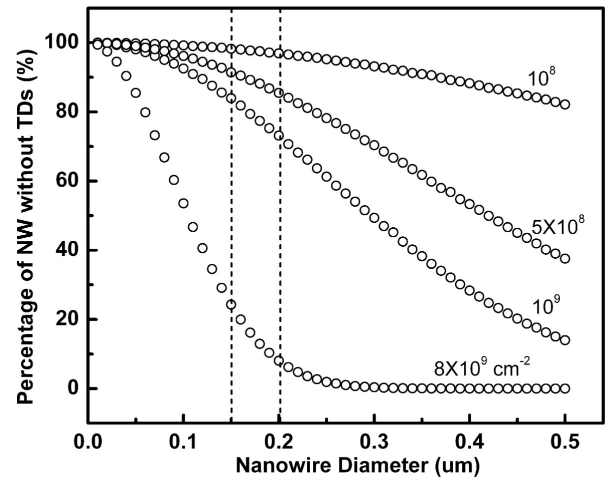
After plasma etch

2 hr wet etch



6 hr

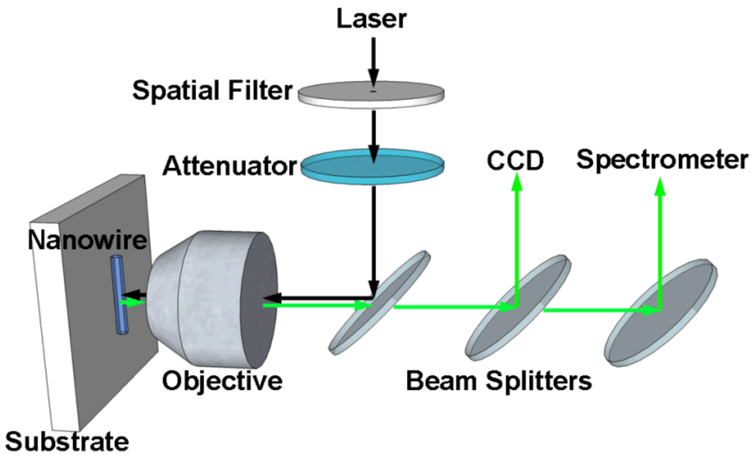
9 hr

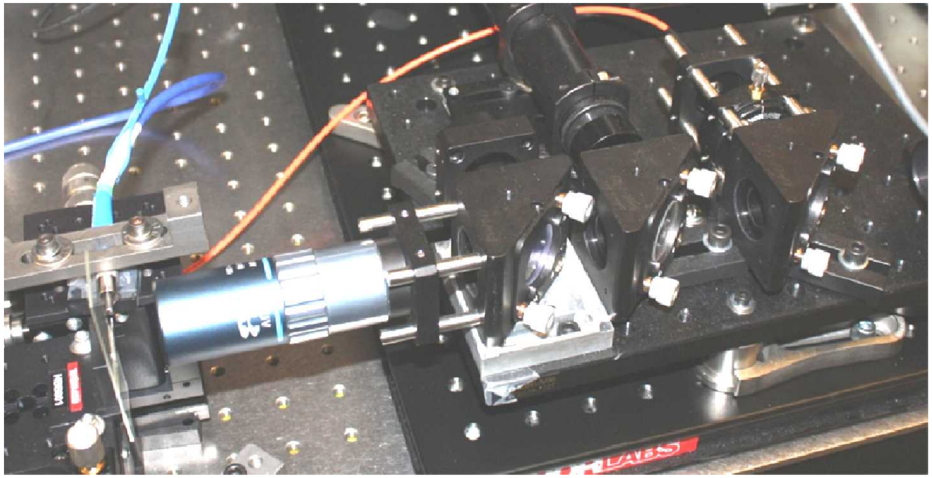


1. Controlled nanowire length and diameter
2. ~90% nanowire are dislocation free
3. High surface quality
4. High material quality

Optics Express, 19, 25528 (2011)

GaN nanorod lasing - µPL setup





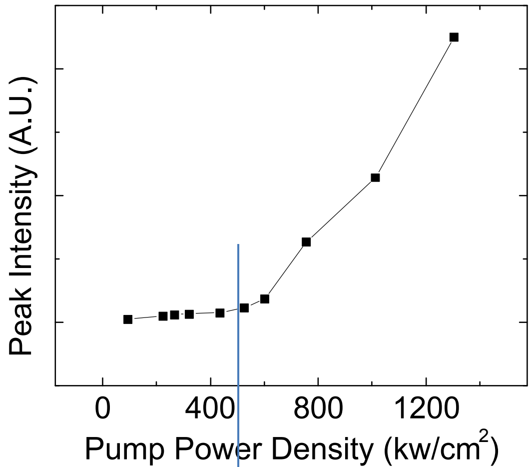
•266 nm pulsed quadrupled YAG laser
•5.2mW, Pulse Width: 0.4ns, Rep Rate: 9.08 kHz, Pulse Energy: 0.64µJ, Peak Power: 1.6kW

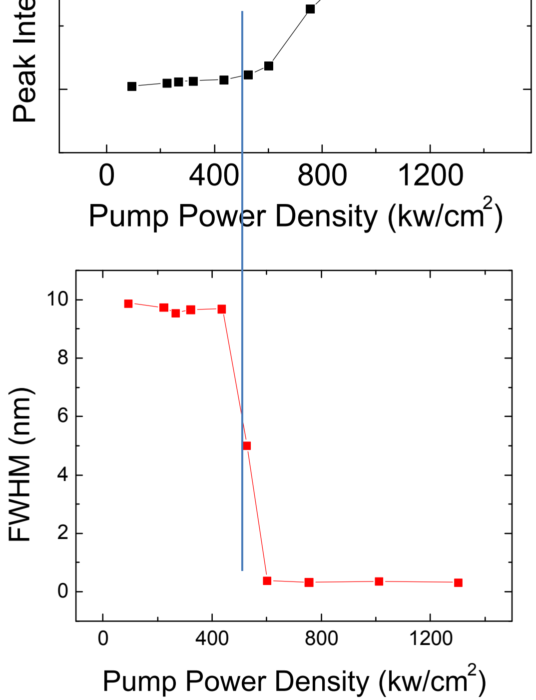
- pump power densities ranging from 15kW/cm^2 to 3MW/cm^2

- 5 µm spot
- Room Temperature

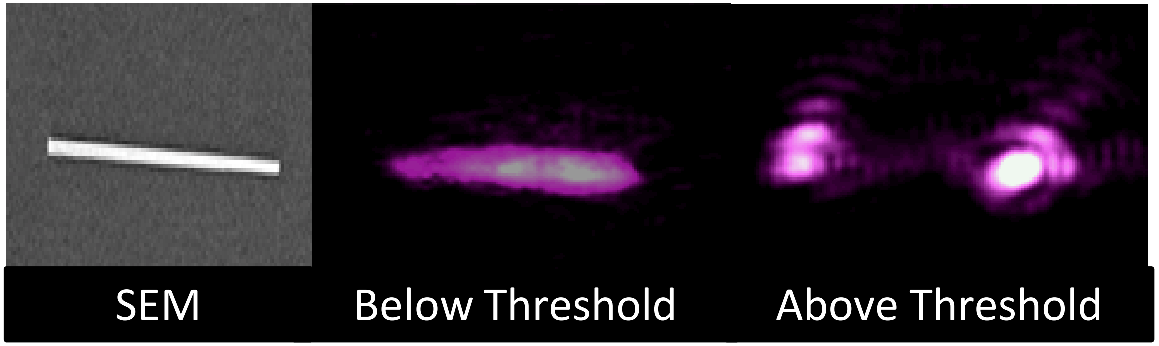
GaN nanowire lasing – diameter effect 250 nm or larger

Threshold ~ 500 kW/cm^2

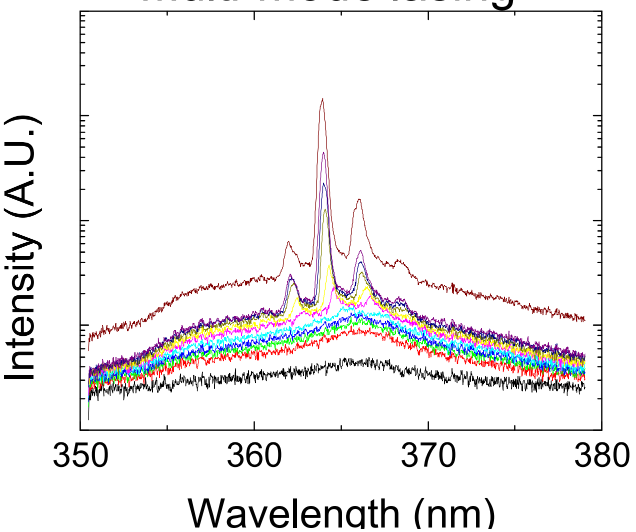




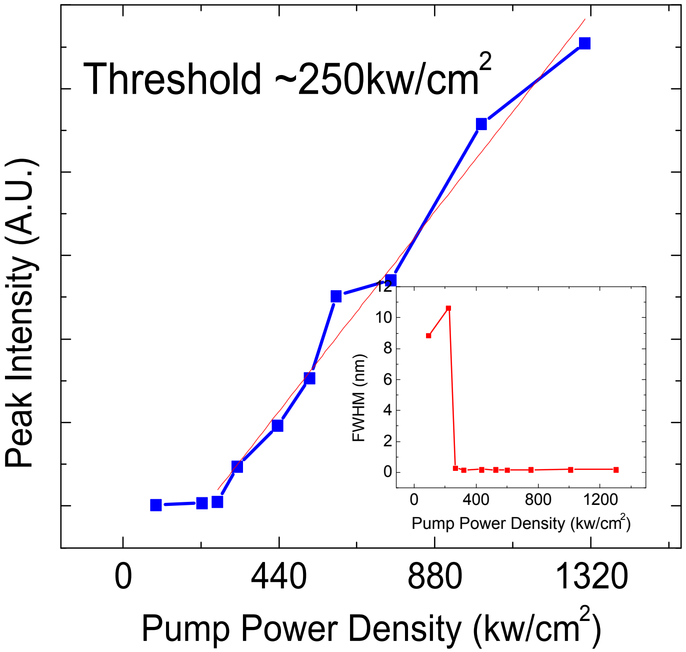
Nanorod dimensions: 250 nm x 4.7 µm (lying flat on sapphire)

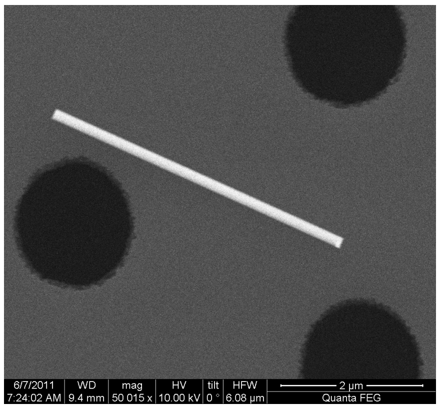


Multi-mode lasing

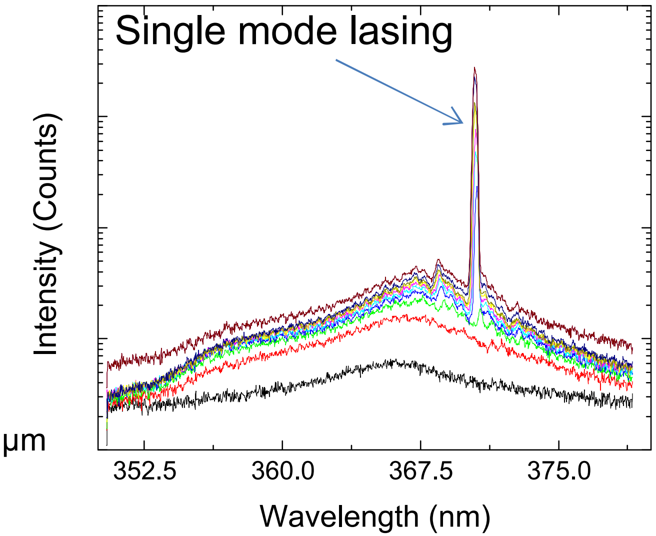


GaN nanowire lasing – diameter effect
~130 nm



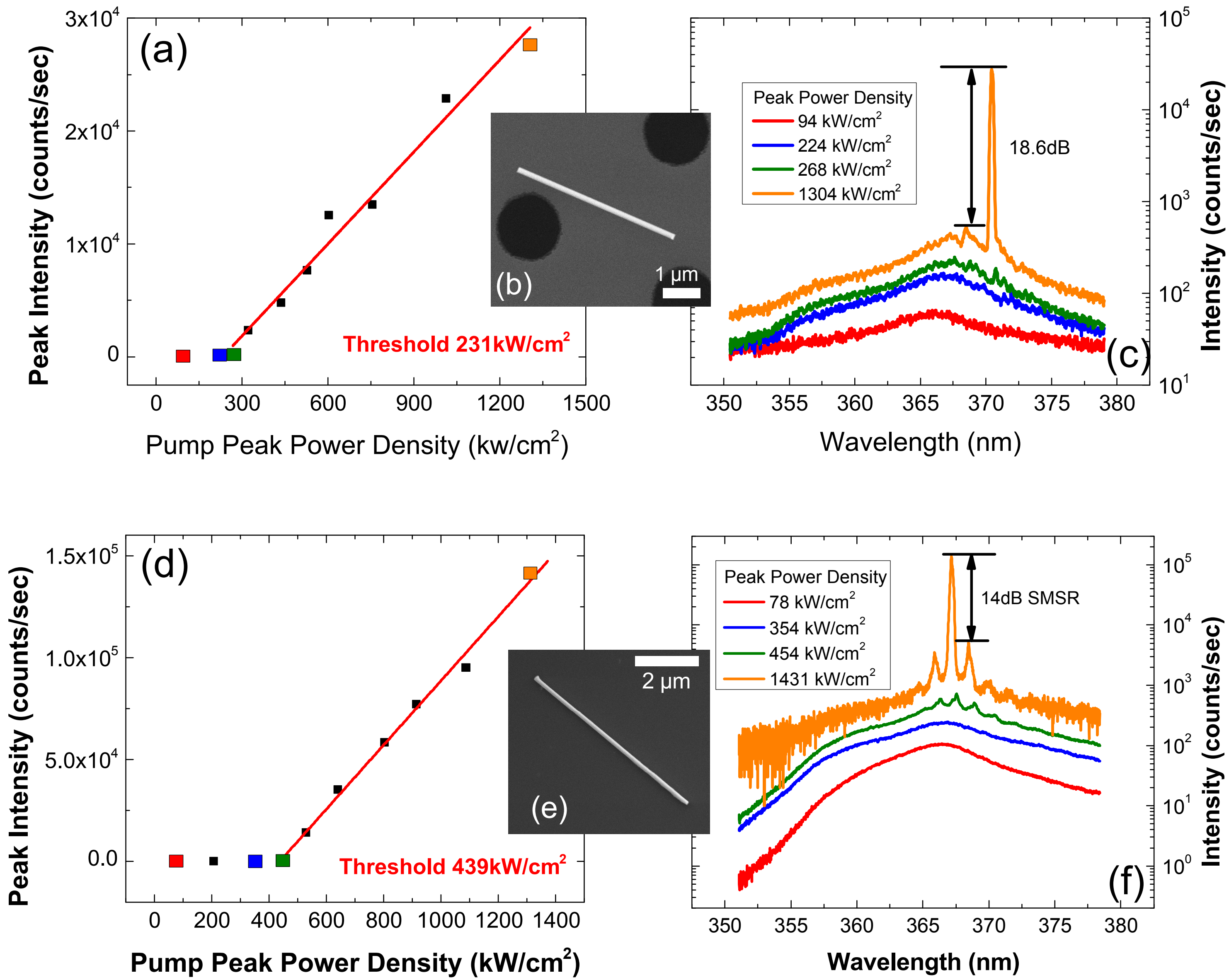


Nanorod dimensions: **130nm** x 4.7µm

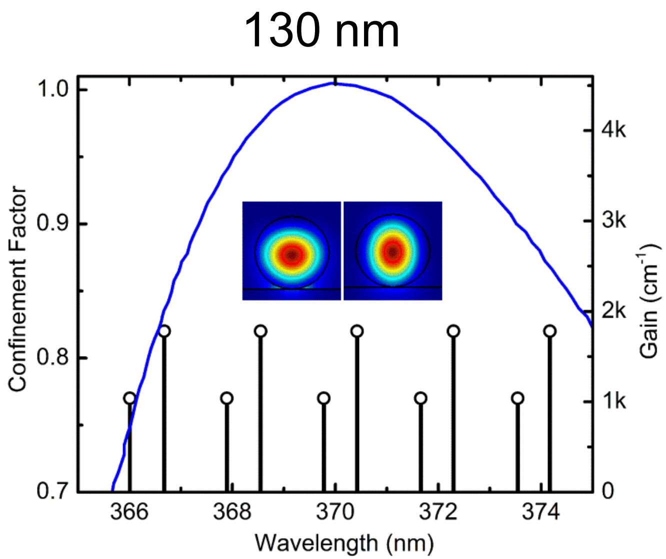


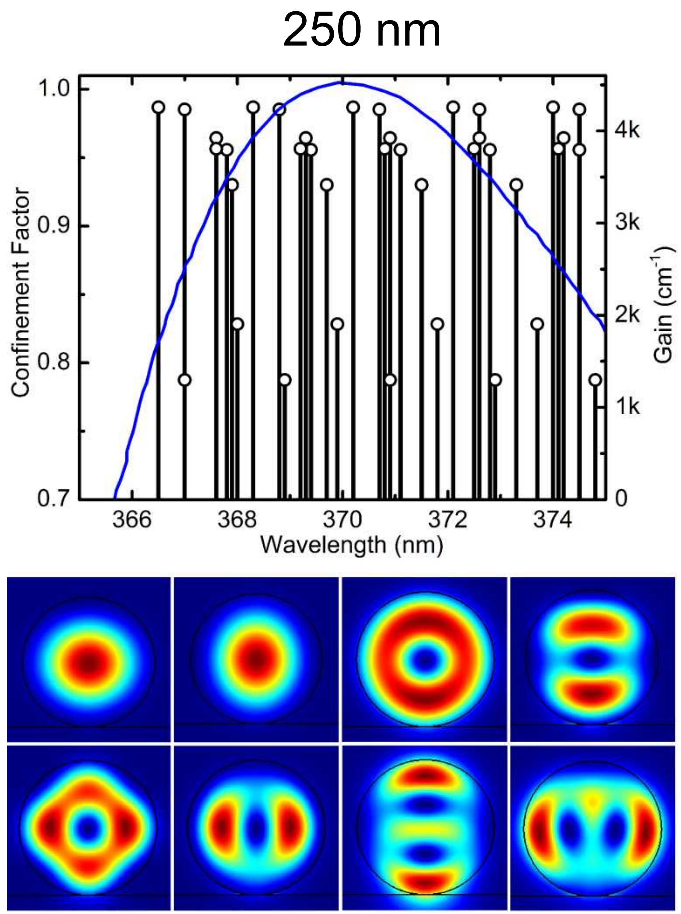
- Narrow-Linewidth (<0.1 nm), **Single-Mode**, 15dB Side Mode Suppression Ratio, and **Low Threshold**

GaN nanorod lasing – length effect
4.7 um vs 7 um

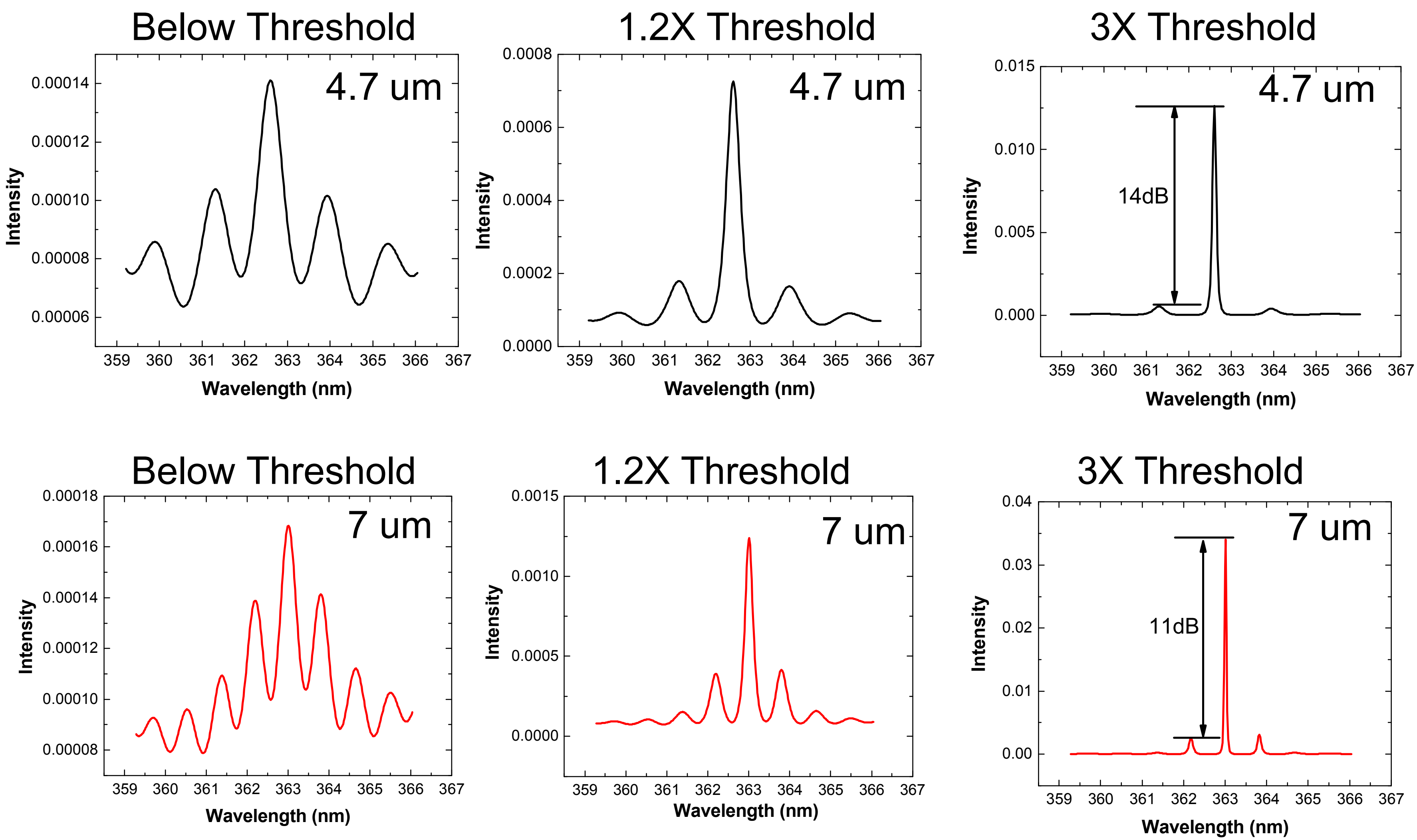


Nanowire geometry influence on optical mode
Discussion 1: possible transverse mode allowed





Nanowire geometry influence on optical mode
Discussion 2: mode competition



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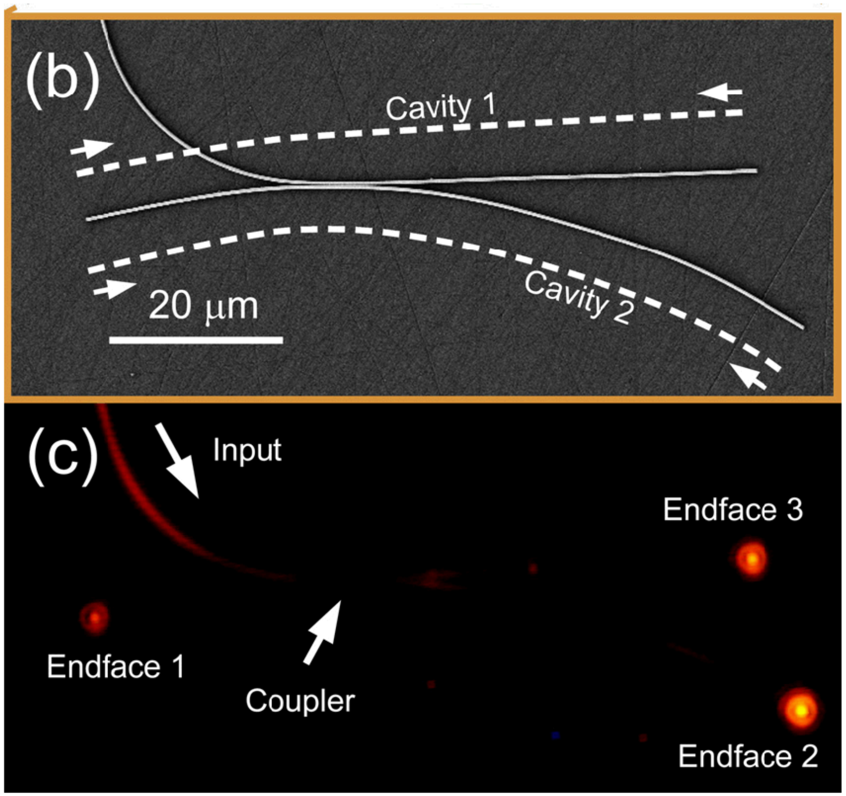
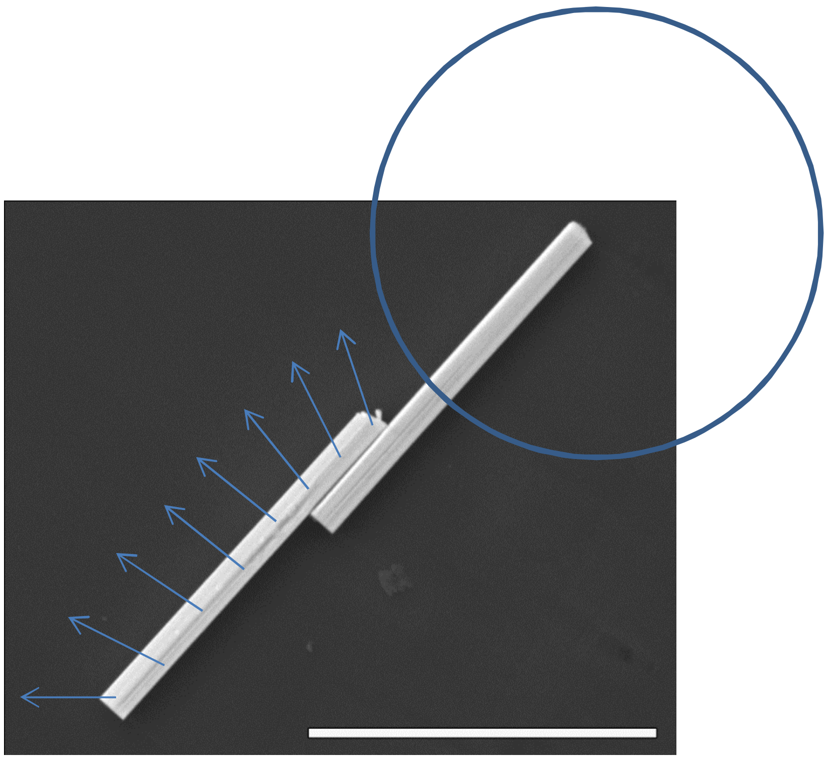
Evanescent wave coupling between nanowires

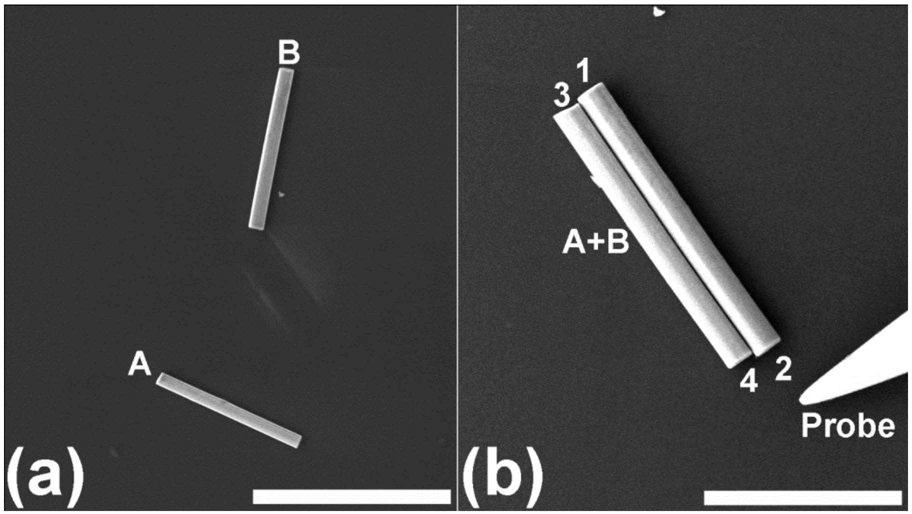


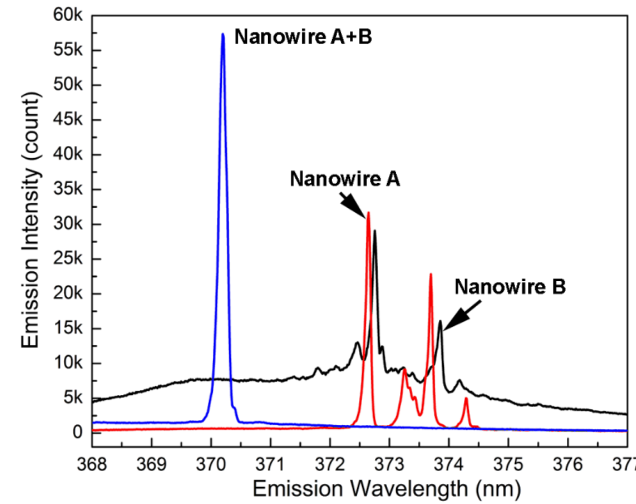
CdSe nanowire coupling
Limin Tong's group
APL 99, 023109 (2011)

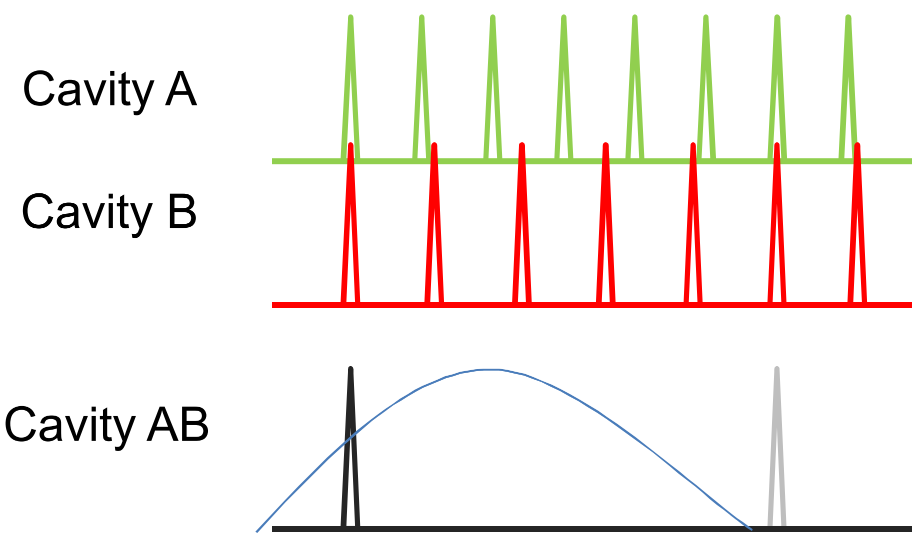


GaN nanowire coupling

Vernier Effect: Single mode selection between coupled cavities







Free Spectra Range > Gain Range/2

1. Individual nanowire shows multiply modes.
2. Coupled nanowires show single mode.
3. Cavities: 12+34+14+23
4. Increased free spectra range

Summary

- Top down: a good way for making high quality GaN nanowires.
- Control nanowire diameter and length to achieve single mode emission.
- nanowire pairs provide mode selection through evanescent wave coupling.
- Near future work: Electrical injected nanowire lasers.