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Nonpolar InGaN/GaN multi-quantum-well core-shell nanowire lasers

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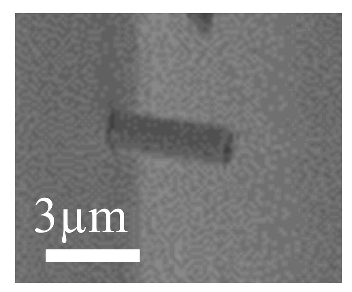
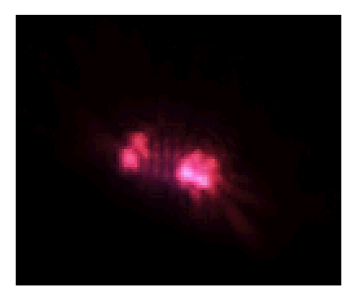
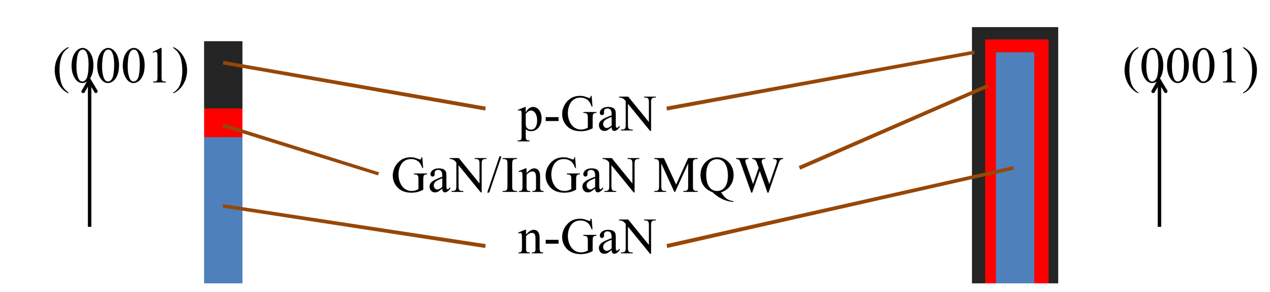
Why III-nitride nanowire lasers?

- Wide direct bandgap range
  - Deep UV to visible to IR
- Strain relaxation
  - Reduce defects
  - Larger compositional range
- Compact size
  - Low power requirement
  - Low threshold
  - Nano-scale on-chip application
  - High speed communication

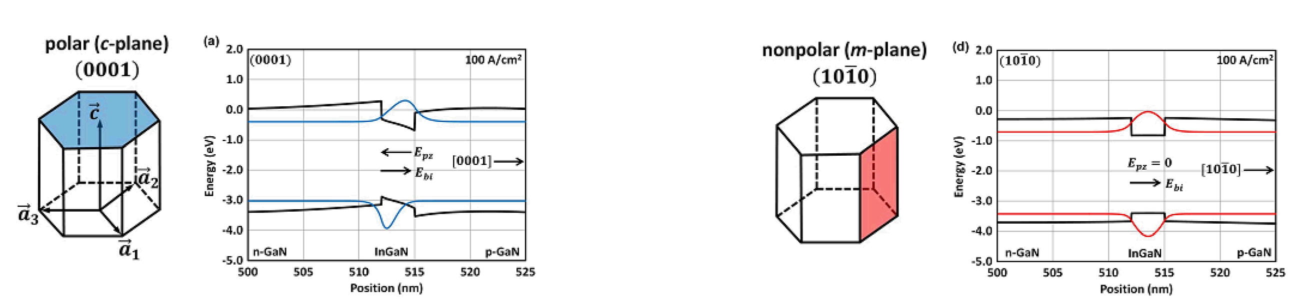




Core-shell vs. Axial nanowire lasers

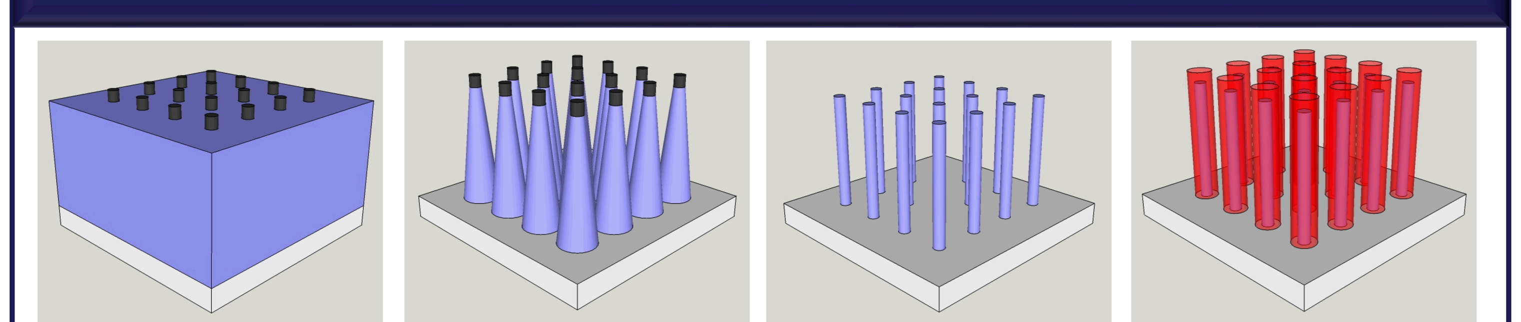


Axial nanowire	Core-shell nanowire
Smaller active region	Larger active region
Polar: Quantum-confined stark effect	**Nonpolar**: No QCSE

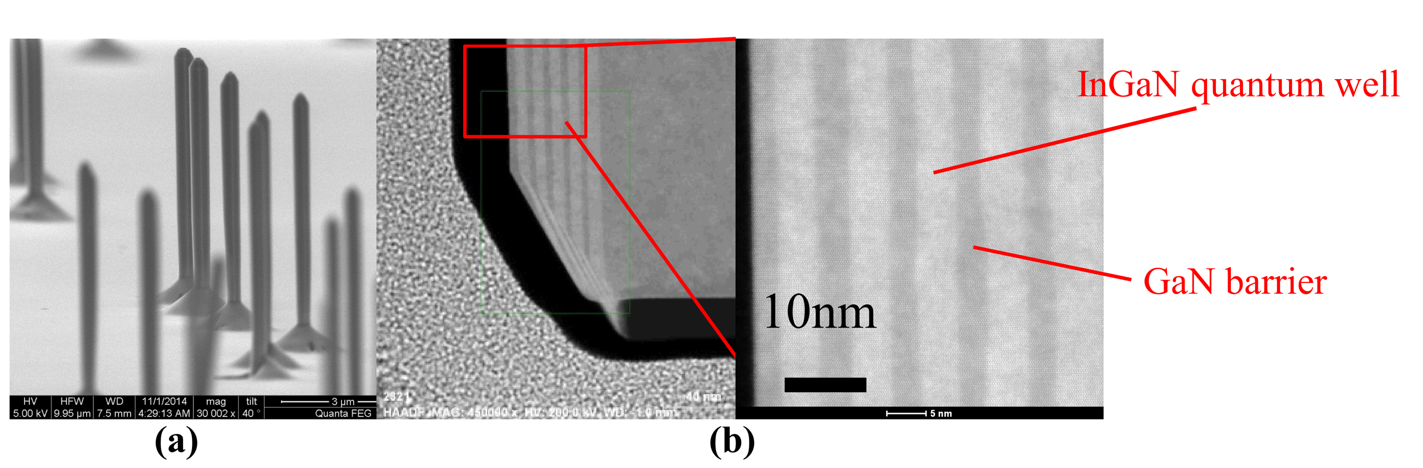


- Higher internal quantum efficiency
- No blue-shifting with increasing current

Top-down two-step etch process

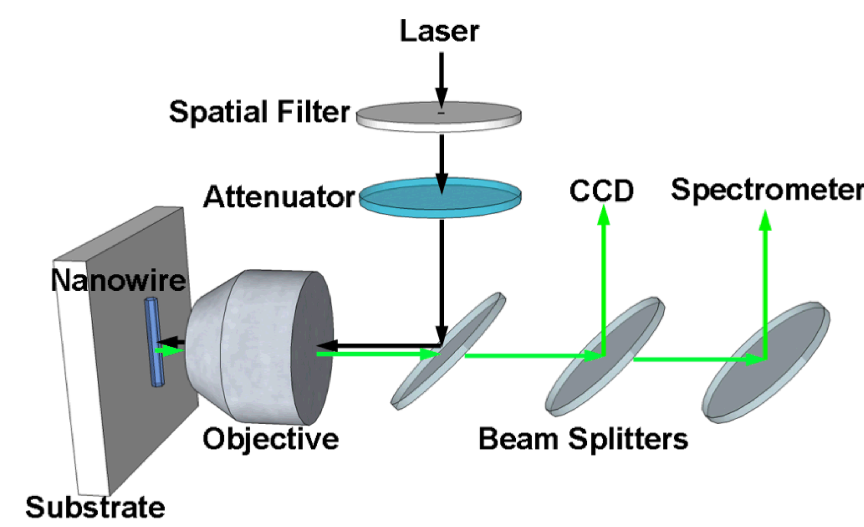


E-beam lithography patterning | ICP dry etch | AZ400K wet etch | Shell layers regrowth by MOCVD



(a) SEM image of as fabricated p-i-n InGaN/GaN MQW core-shell nanowires. The diameters of the nanowires are 400-600 nm. Slightly tapered sidewalls are observed due to different regrowth rates along the nanowire axis. **(b)** High resolution cross-sectional STEM images of a core-shell nanowire.

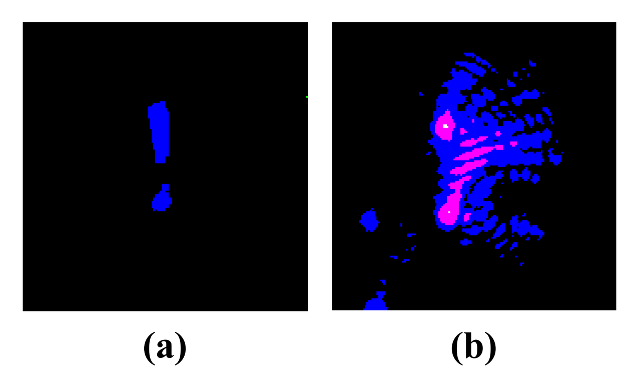
Optical characterization setup



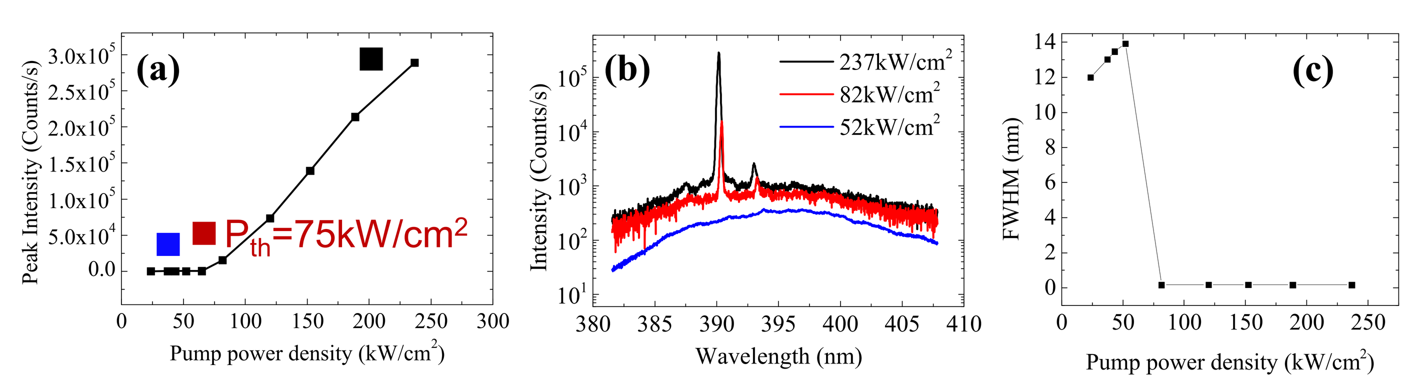
Pump laser:

Nd:YAG laser	@266nm
Pulse duration:	400 ps
Rep rate:	10 kHz
Duty cycle:	0.0004%
Tunable spot size:	>1μm

Lasing from core-shell nanowire lasers

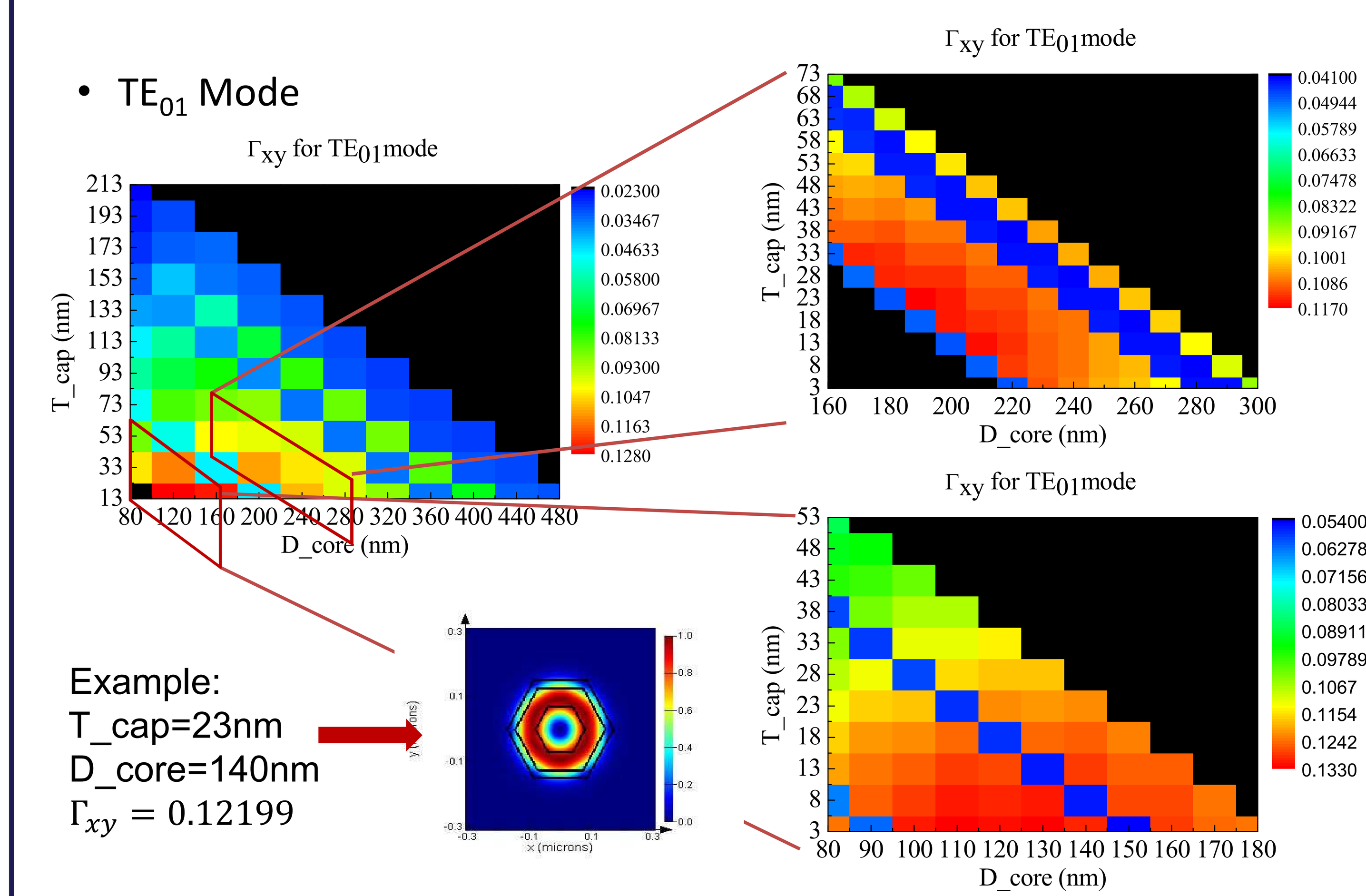


(a) When the nanowire was optically pumped below lasing threshold, a uniform intensity across the nanowire was observed. **(b)** When the nanowire was excited above threshold, the intensities at both ends of the nanowire were much stronger than in the middle. Clear interference fringes also indicate a spatially coherent emission.

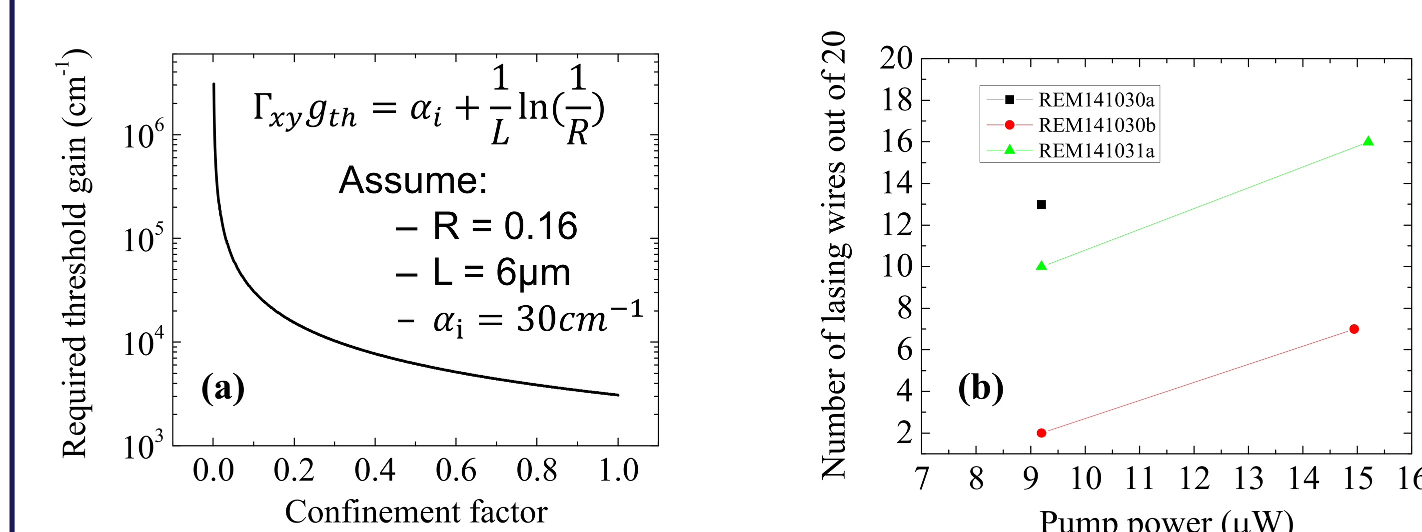


(a) L-L curve and **(b)** μ-PL spectra at 3 different excitation levels, and **(c)** spectral lindwidth of an InGaN/GaN core-shell nanowire laser. When the nanowire laser is excited below threshold, the peak intensity increases linearly with a smaller slope as the pump power density increases, indicating spontaneous emission dominates. A broad-band spectrum centered at 397.5nm is observed with a full width half maximum (FWHM) of 15nm. When the nanowire laser is pumped above threshold, the peak intensity increases dramatically, due to stimulated emission. Narrow-band lasing peaks with a FWHM of 0.17nm were also observed.

Simulation of transverse confinement factor



Simulation of transverse confinement factor (Γ_{xy}) of TE_{01} mode as a function of core diameter and shell thickness. Γ_{xy} varies from 12% to 2% with different structure design. This variation results in different lasing thresholds of the core-shell nanowire lasers.



(a) Required threshold gain as a function of the confinement factor. The required threshold gain can be reduced by 5-10 times with a slightly higher confinement factor. **(b)** Number of lasing nanowires (out of 20) with different pump powers for 3 samples with different growth conditions. Significant variation of lasing threshold was observed.

Conclusion

- Fabricated nonpolar InGaN/Gan MQW core-shell nanowire using a combination of top-down two-step etch process and regrowth process
- First experimental demonstration of lasing from nonpolar GaN/InGaN MQW core-shell nanowire by optical pumping
- Simulated transverse confinement factors with different nanowire geometries.

References

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