Hybrid single nanowire photonic crystal structures





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Semiconductor Nanowire for Photonics

Semiconductor nanowires as building blocks for photonic circuits

Semiconductor nanowires provide an active medium

- Direct band gap semiconductors (e.g. CdS, GaN nanowires)



C.J. Barrelet, Y. Wu, D. C. Bell, C. M. Lieber, *J. Am. Chem. Soc.* **125**, 11498 (2003)



Single GaN Nanowire Laser



S. Gradecak, F. Qian, Y. Li, H.-G. Park, C.M. Lieber, Appl. Phys. Lett. 87, 173111 (2005).

Optically Pumped InGaN/GaN Multi-quantum Well Nanowire Laser



F. Qian, Y. Li, S. Gradecak, H.-G. Park, Y. Dong, Y. Ding, Z.L. Wang, C.M. Lieber, Nature Mater. 7, 701 (2008).

Photonic Crystals



http://ab-initio.mit.edu/photons/tutorial/

- Photonic crystals: periodic dielectric structures with the lattice constant Λ on the order of the wavelength of light λ .

 $\lambda \thicksim \mathsf{n}_{\text{eff}} \, \Lambda$

- Photonic crystals enable:
- 1. Inhibition of the spontaneous emission
- 2. Localized emission in defects
- 3. Optical cavities
- 4. Waveguide structures







Self-organized assembly (UK)

Photonic Crystal Laser

Freestanding slab laser structure (current injection)



3D confinement of light in a photonic crystal slab:

- (1) Photonic band gap (in-plane confinement)
- (2) Total internal reflection in the slab plane (vertical confinement)

Photonic crystal slab + Active medium (QWs)

\rightarrow Photonic crystal laser

- ultra-low threshold
- promising light source for nanophotonics

Localized Emission in 1D Photonic Crystals



Nanowire photonic crystal structures can contain engineered defects.



These measurements demonstrate
1. Light inhibition by the photonic crystal
2. Localized emission at the site of engineered defects

Optically Pumped Nanowire PC Waveguide SEM of the CdS nanowire facing the straight waveguide output CdS scattering nanowire waveguide site d = 80nm 5 microns $l = \sim 5 \mu m$ Photoluminescence superimposed on the SEM image 5 microns (PL spectra) input output 300 300 700 400 500 600 700 400 500 600 Wavelength (nm) Wavelength (nm)

H.-G. Park, C.J. Barrelet, Y. Wu, B. Tian, F. Qian, C.M. Lieber, *Nature Photonics* 2, 622 (2008).