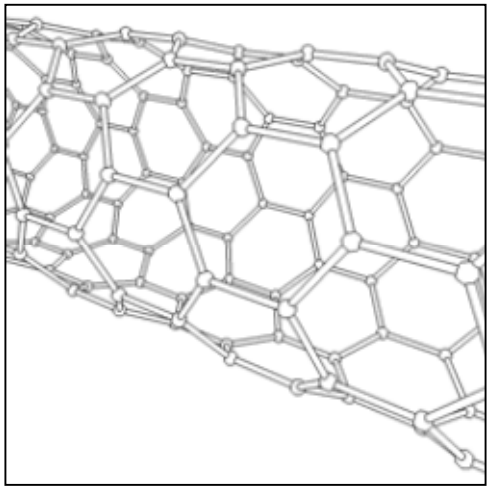
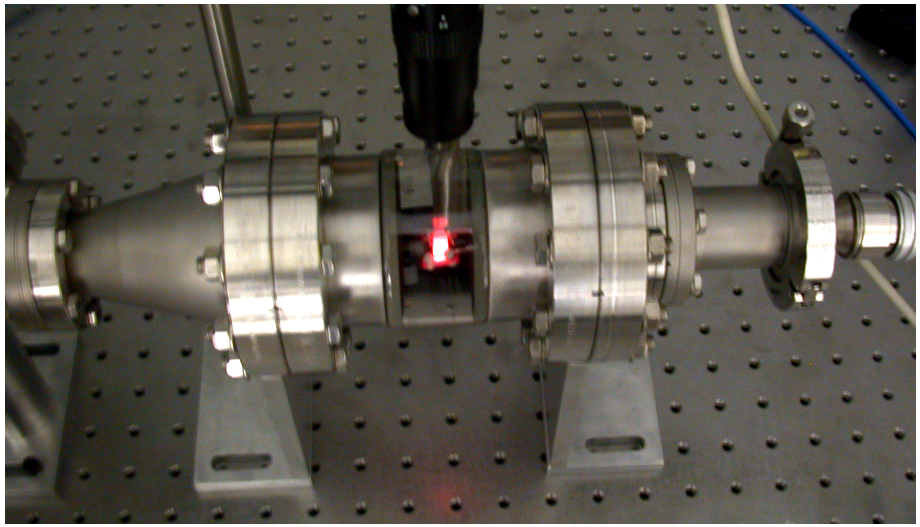
# Raman and luminescence imaging for the characterization of CNT



http://fr.wikipedia.org/wiki/

Synthesis Method
Raman imaging
PL/PLE/imaging

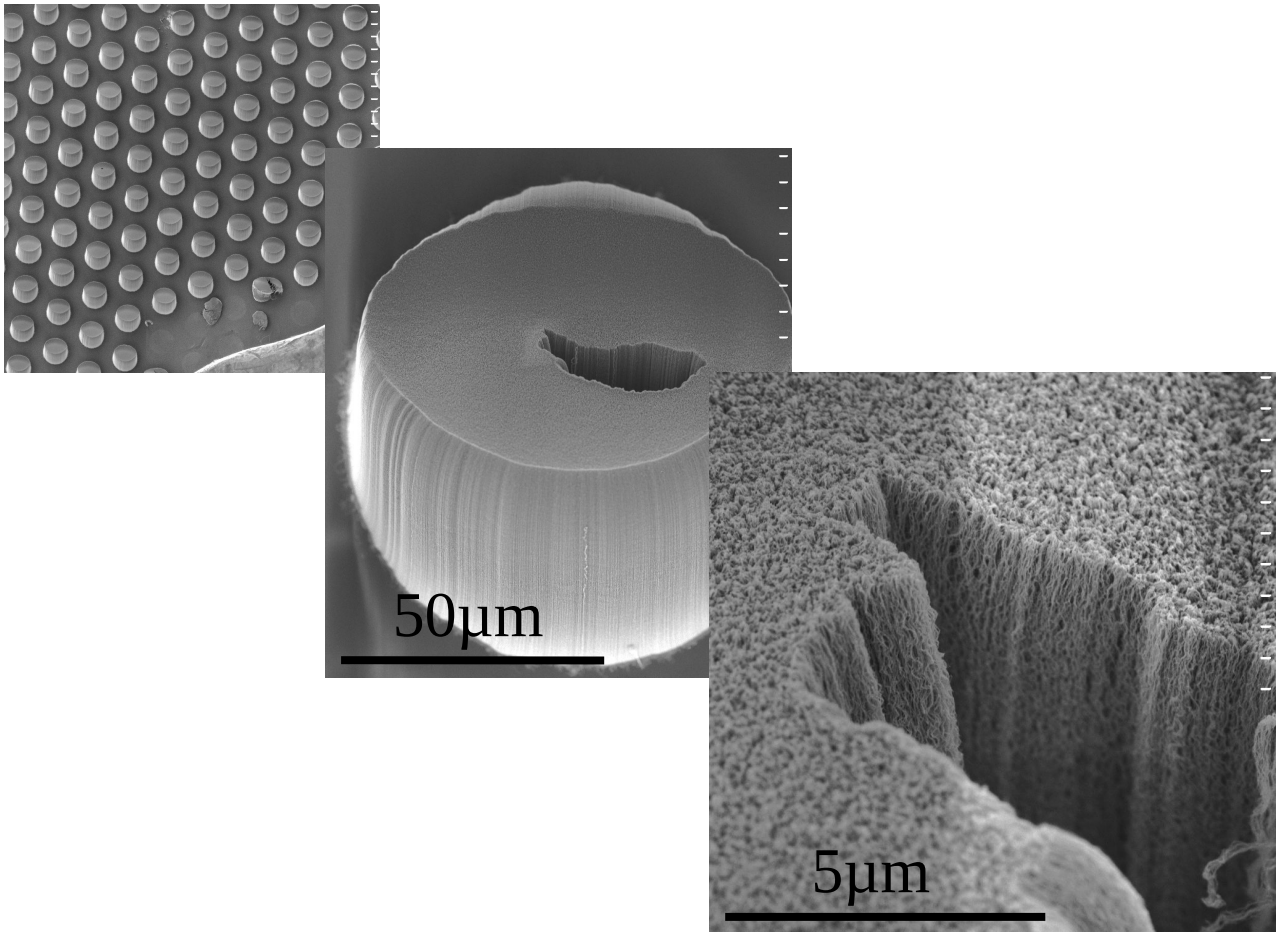
# Synthesis



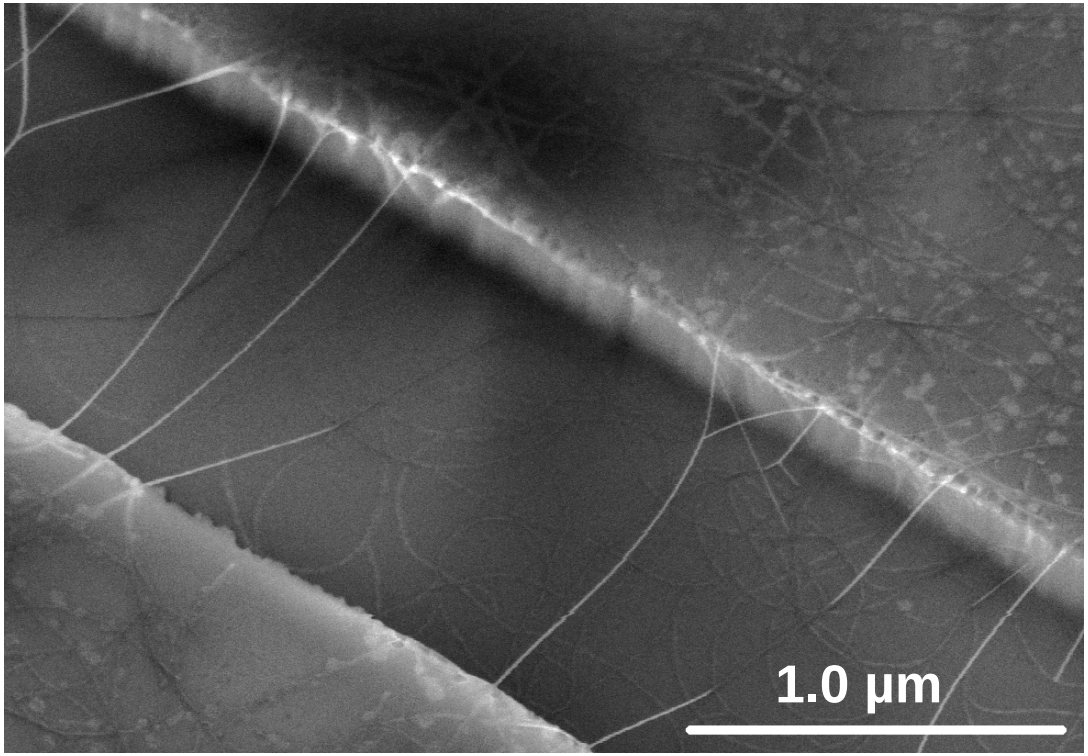
**Cold wall CVD**

*<1nm Fe/Co Catalyst film*
*Ethanol/Ethylene carbon source*
*$SiO_2$/Si substrate*

# Synthesis: nanotube forest

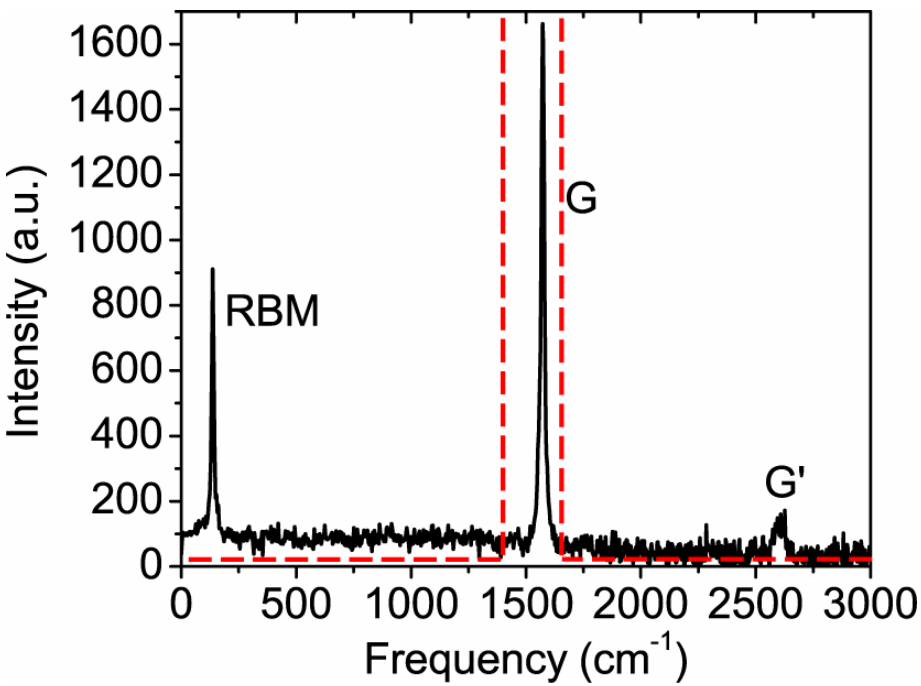


# Synthesis: suspended SWNTs

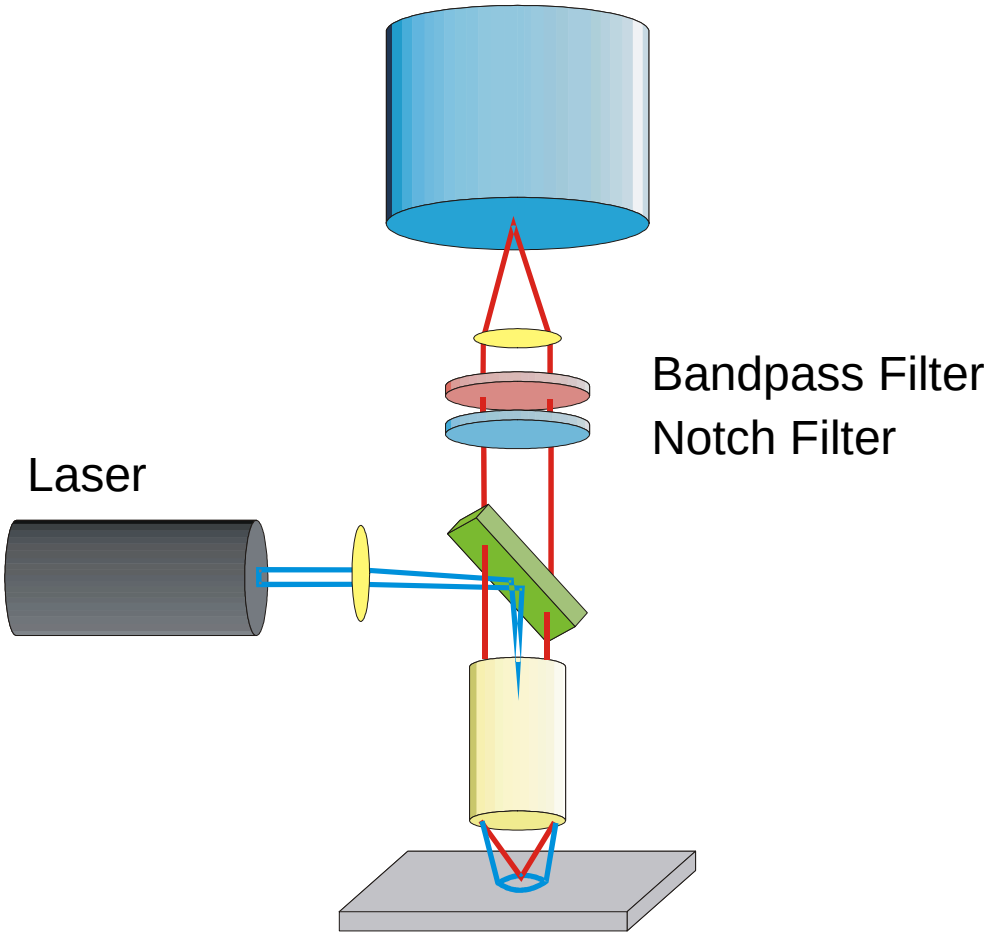


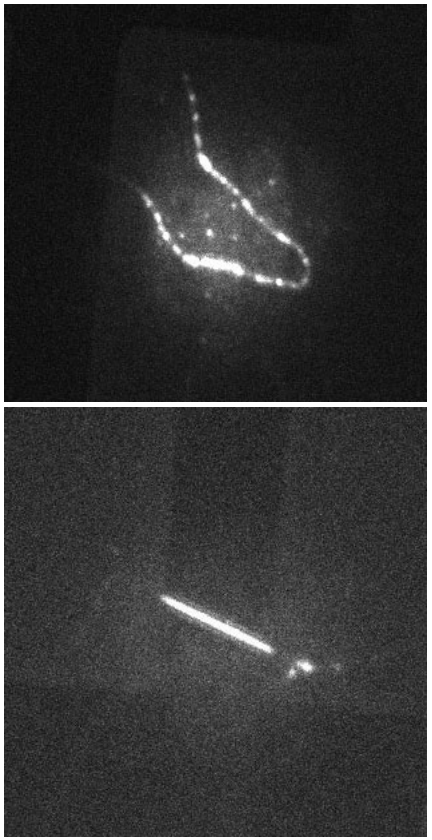
# Raman imaging

# Raman imaging

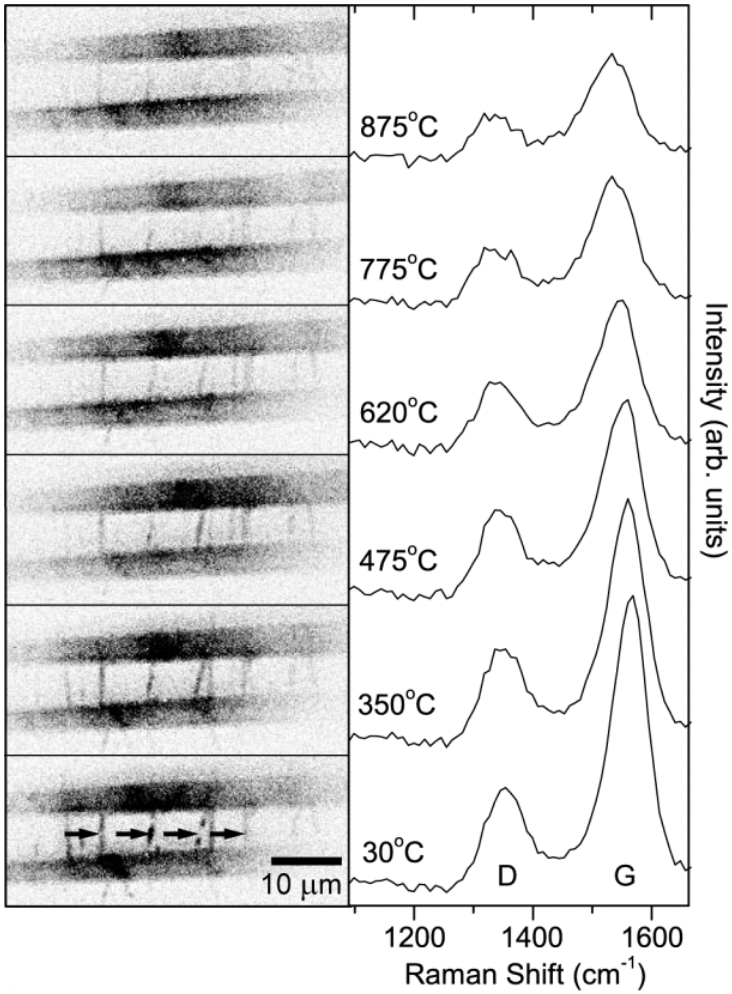


# Global Raman imaging



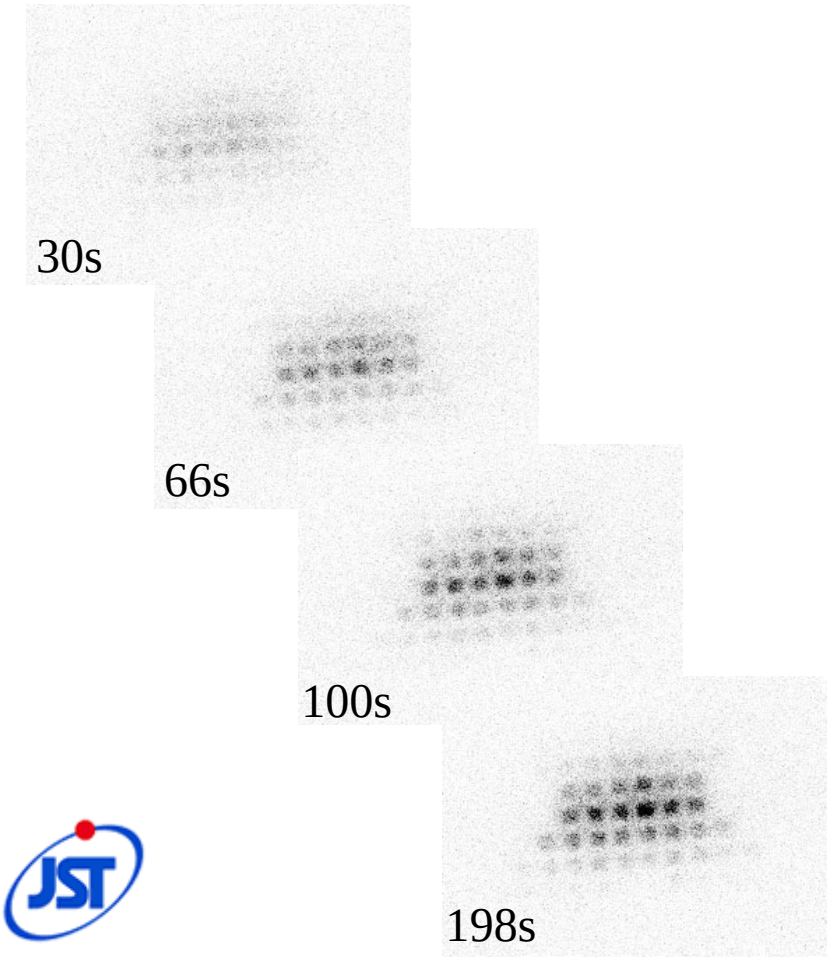



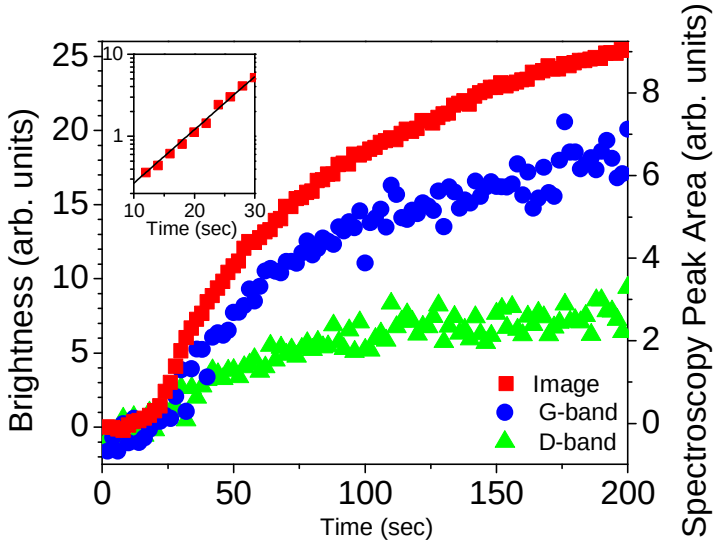
# High-T Raman imaging

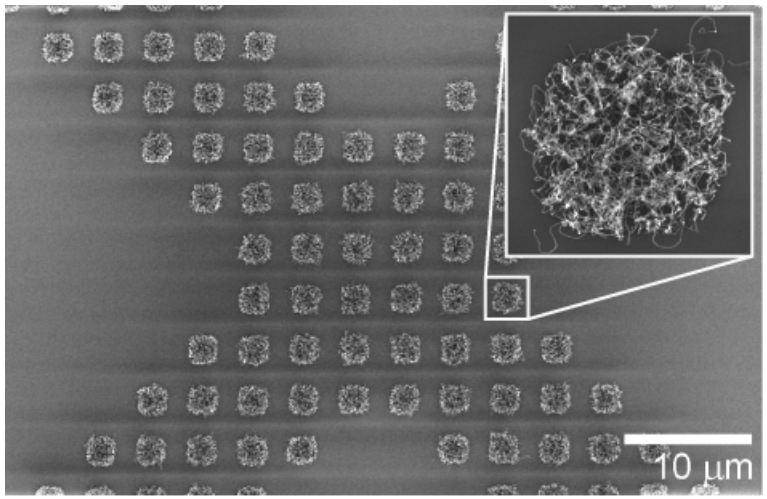



Nanotech **18**, 165707 (2007)

# In situ Raman

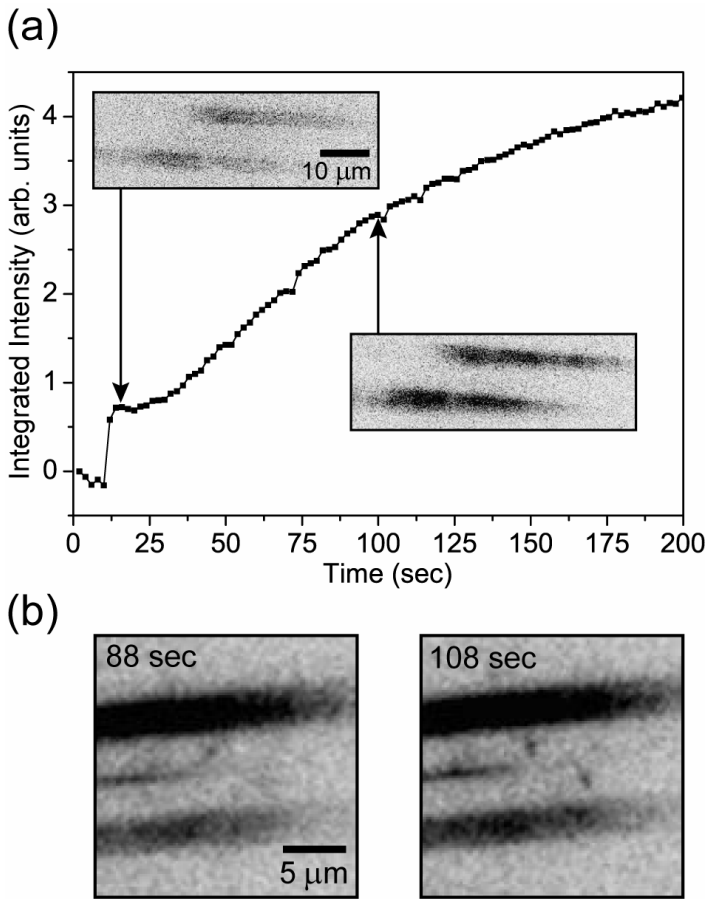


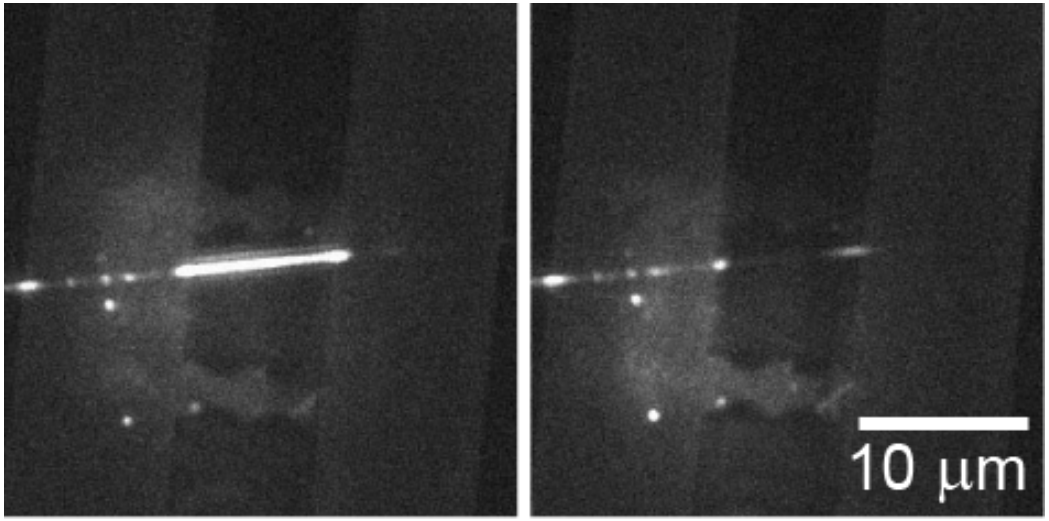

Nanotech **18**, 165707 (2007)

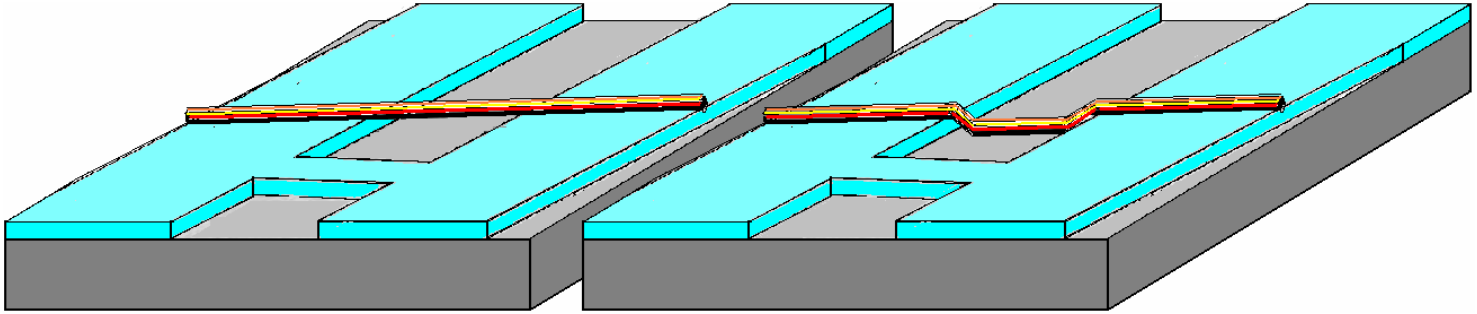
# In situ Raman




Nanotech **18**, 165707 (2007)

# Raman: optical manipulation



PRB **73**, 235410 (2006)

# PL imaging

# Photoluminescence

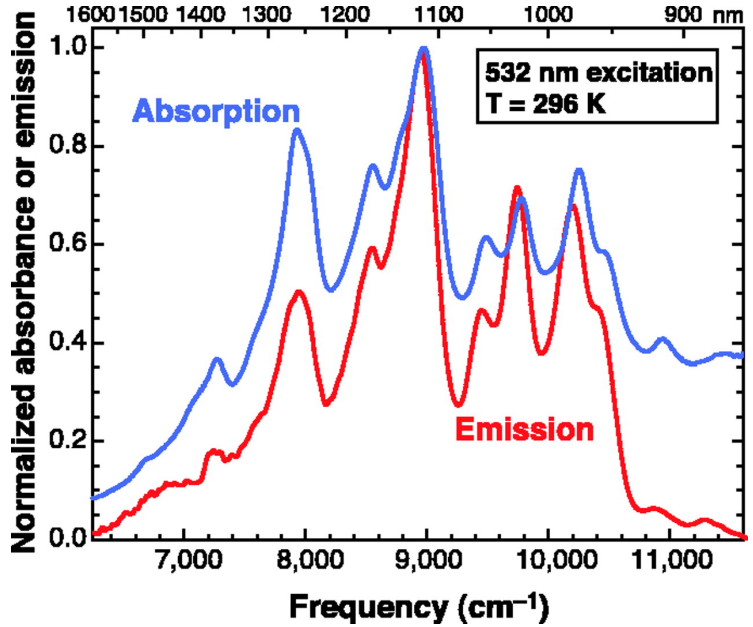
## Band Gap Fluorescence from Individual Single-Walled Carbon Nanotubes

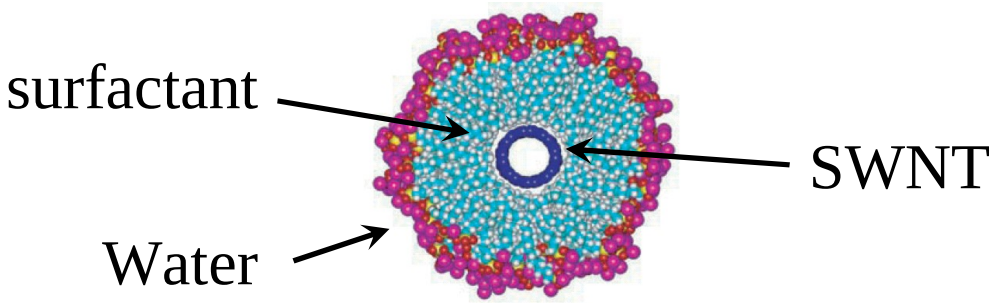
Michael J. O'Connell,[1] Sergei M. Bachilo,[1] Chad B. Huffman,[1] Valerie C. Moore,[1] Michael S. Strano,[1] Erik H. Haroz,[2] Kristy L. Rialon,[1] Peter J. Boul,[1] William H. Noon,[3] Carter Kittrell,[1] Jianpeng Ma,[3,4] Robert H. Hauge,[1] R. Bruce Weisman,[1] Richard E. Smalley[1,2*]

Fluorescence has been observed directly across the band gap of semiconducting carbon nanotubes. We obtained individual nanotubes, each encased in a cylindrical micelle, by ultrasonically agitating an aqueous dispersion of raw single-walled carbon nanotubes in sodium dodecyl sulfate and then centrifuging to remove tube bundles, ropes, and residual catalyst. Aggregation of nanotubes into bundles otherwise quenches the fluorescence through interactions with metallic tubes and substantially broadens the absorption spectra. At pH less than 5, the absorption and emission spectra of individual nanotubes show evidence of band gap–selective protonation of the side walls of the tube. This protonation is readily reversed by treatment with base or ultraviolet light.

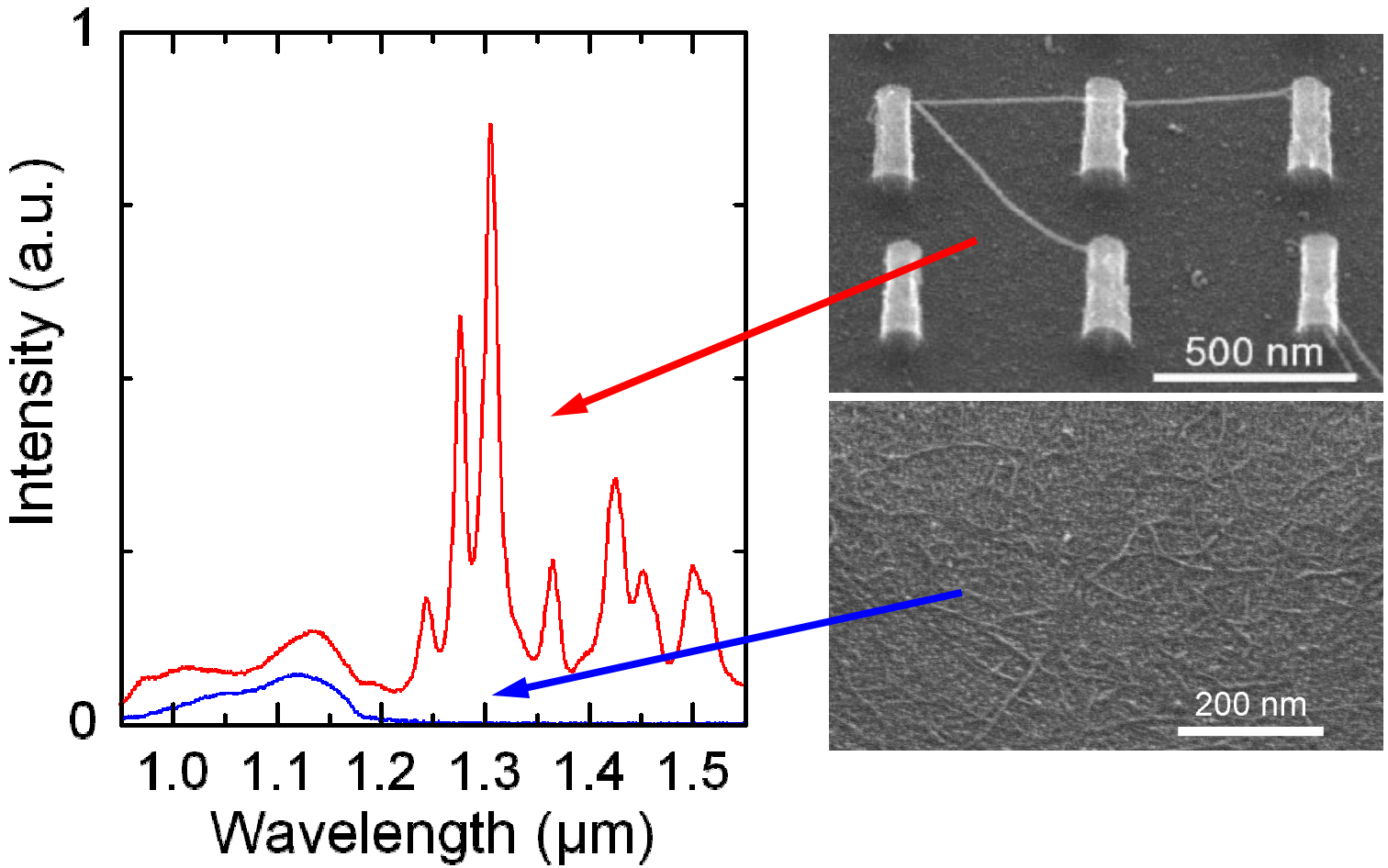
gle-walled carbon nanotubes are elongat- nembers of the fullerene family (*1*) that currently the focus of intense multidisci- ary study because of their unique physical chemical properties and their prospects practical applications (*2*). A major obsta- polarizable, smooth-sided fullerene t readily form parallel bundles or ropes w van der Waals binding energy of ~50 per micrometer of tube-tube contact (*3* This bundling perturbs the electronic s ture of the tubes, and it confounds al

Science Vol.297 p.593 26 July 2002



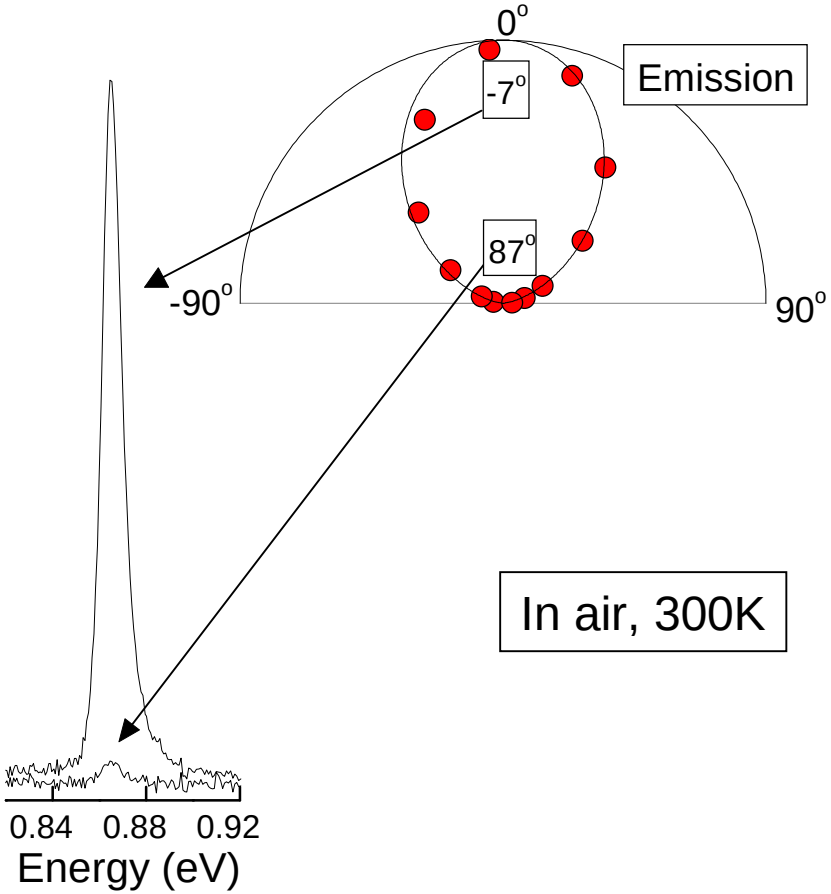



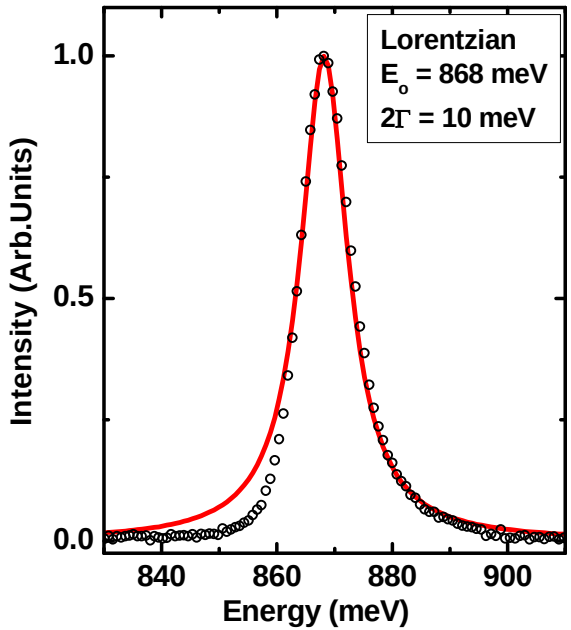
# Our first PL




PRL **90**, 217401 (2003)

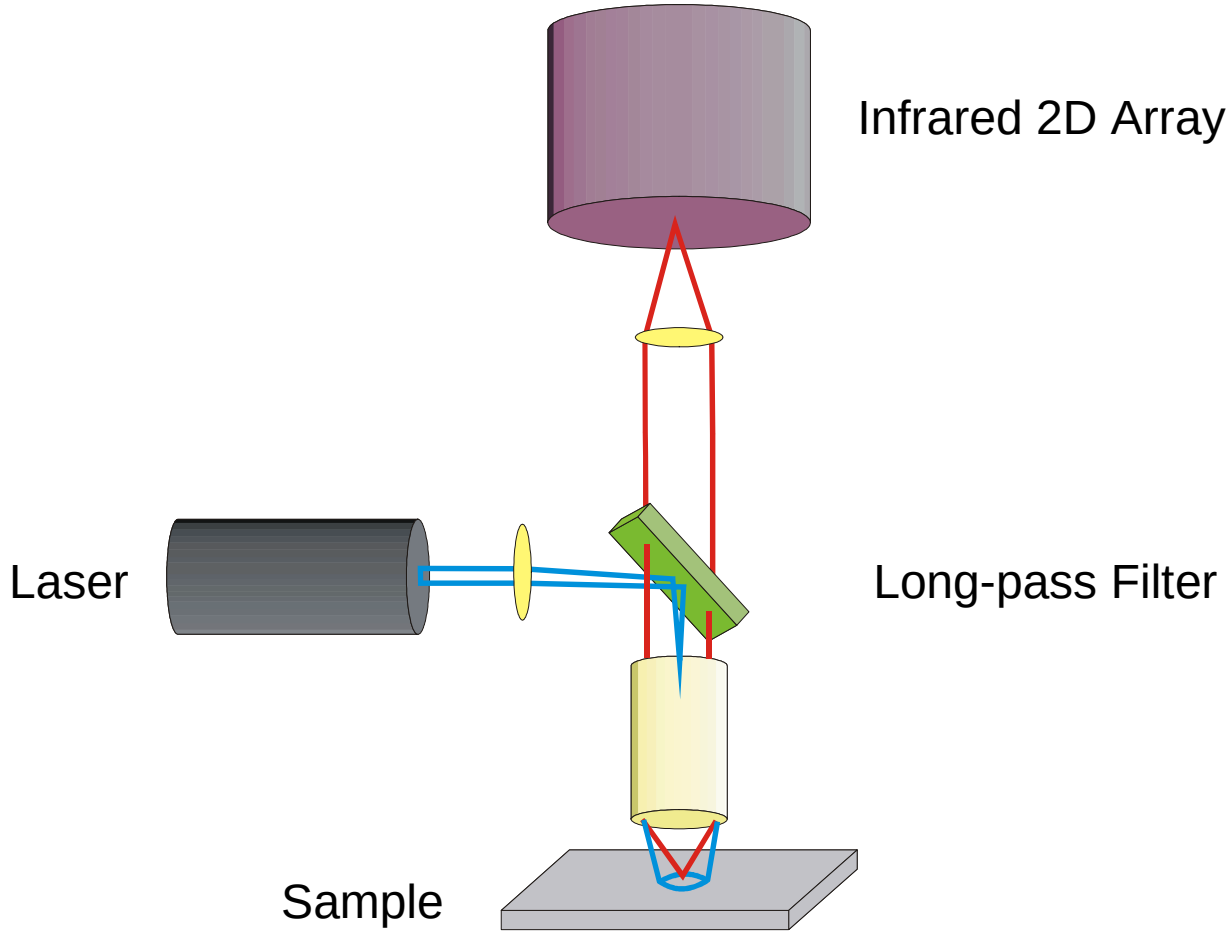
# PL: single nanotube




PRB **69**, 075403 (2004)

# PL imaging

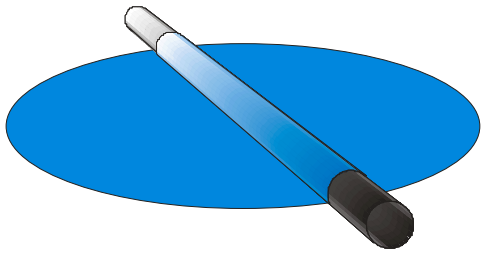


# Nanotube PL image

4 mW,
820 nm

$$\eta = \frac{P_e \lambda_e S}{P_i \lambda_i S_T}$$

145 pW,
1400 nm

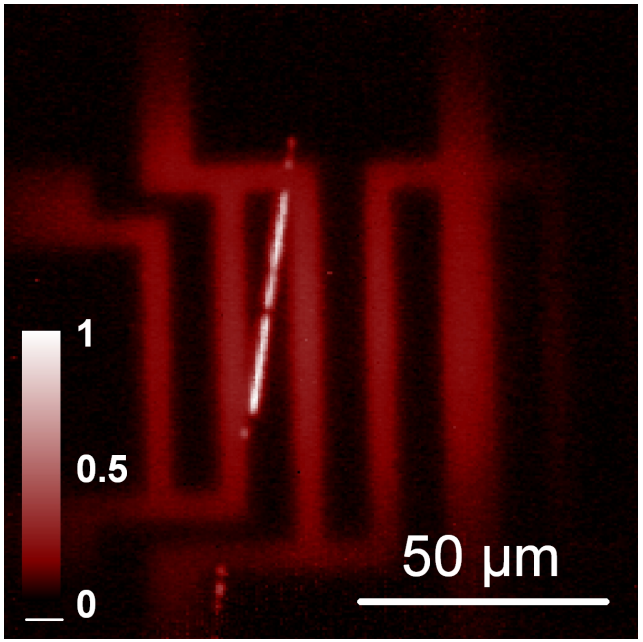


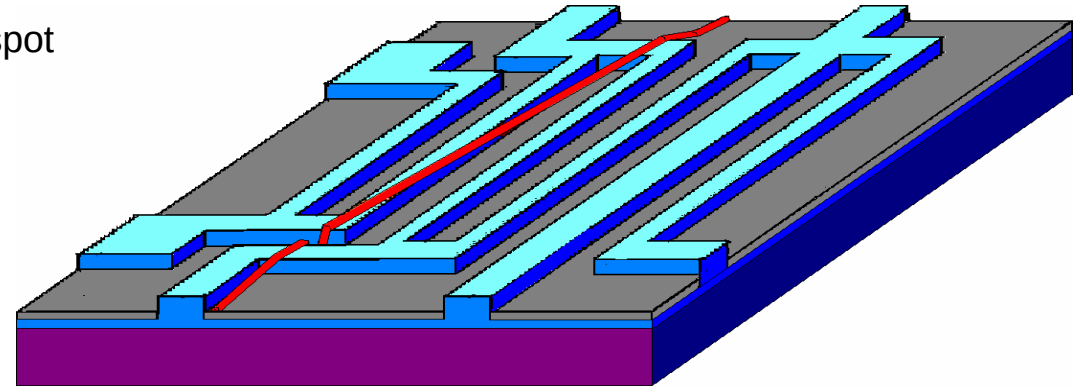
$\eta \sim 7\%$

A=0.6%

40 μm diameter spot

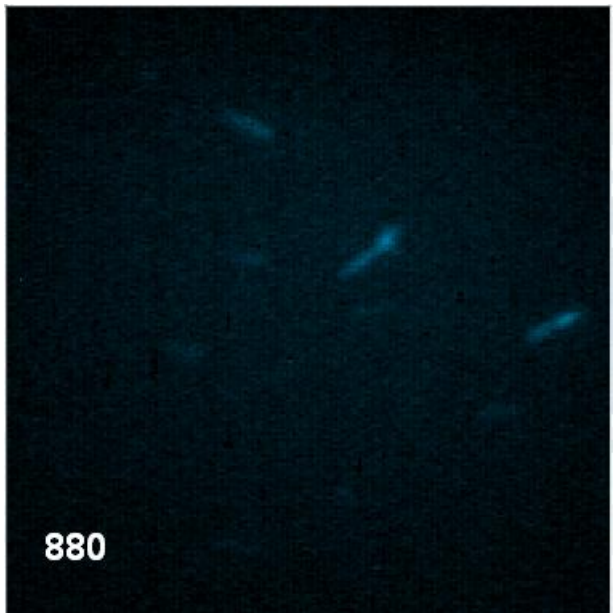
41 μm long, ~1.2 nm diameter

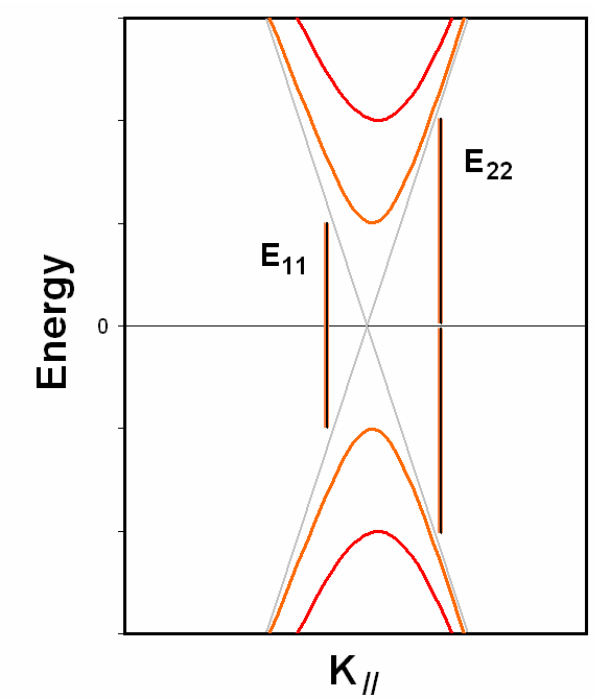


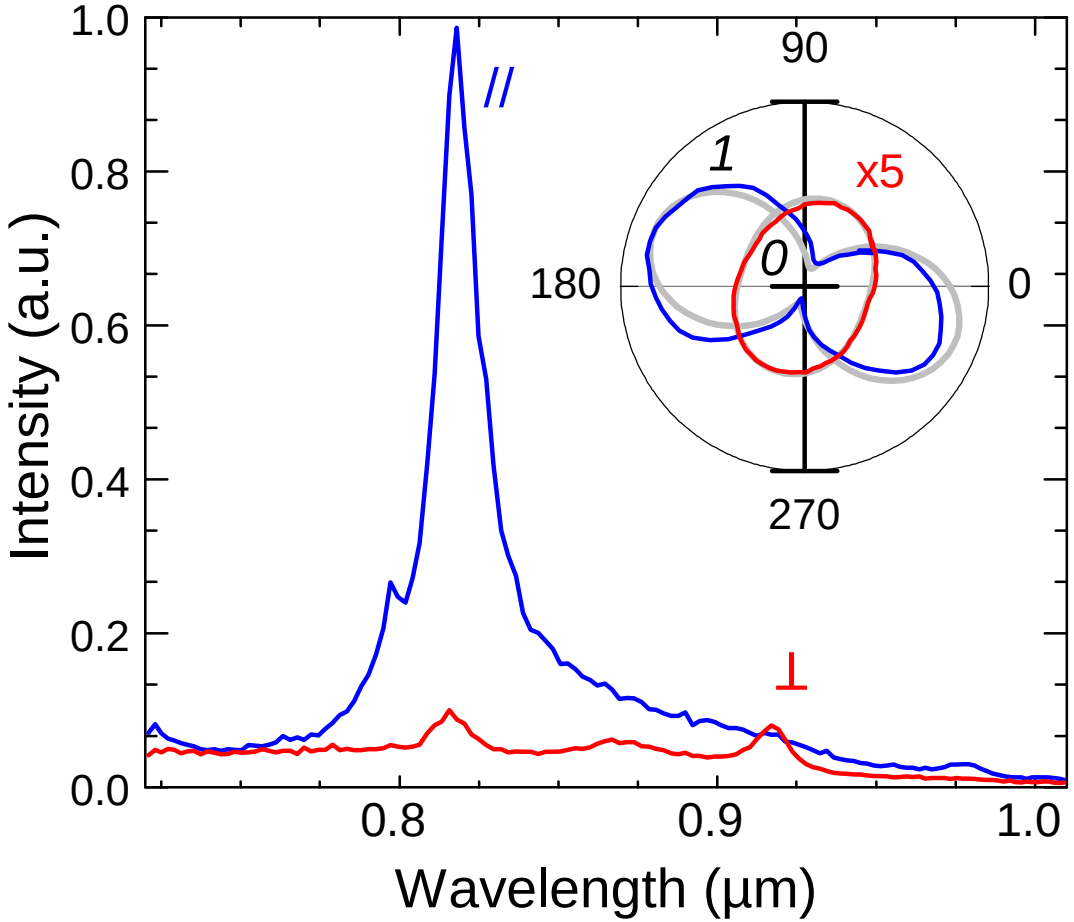
NanoLetters **6**, 1603 (2006)

# From PL imaging to PLE



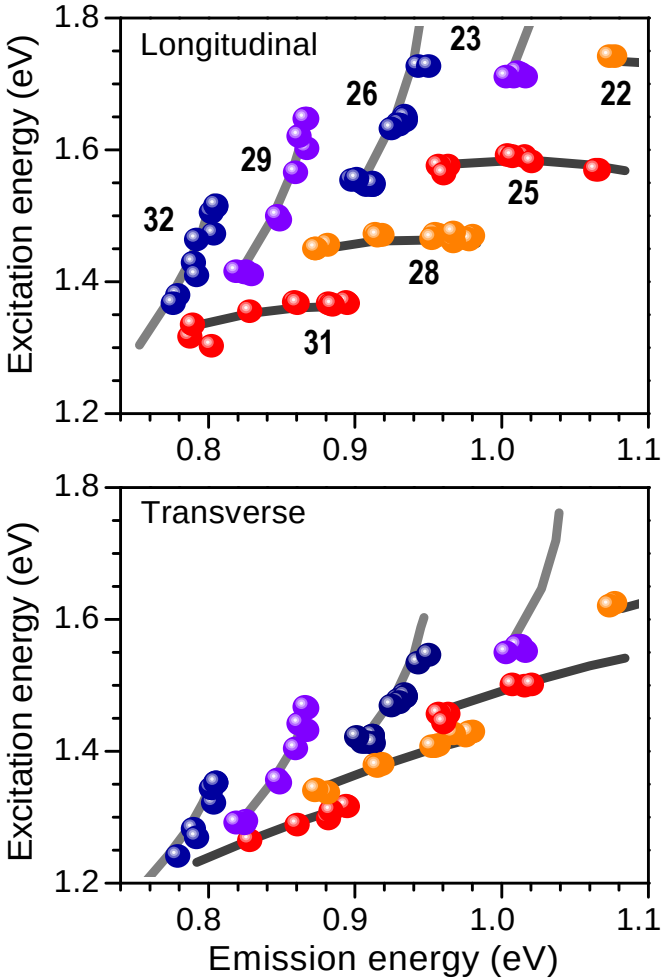
# PLE from imaging

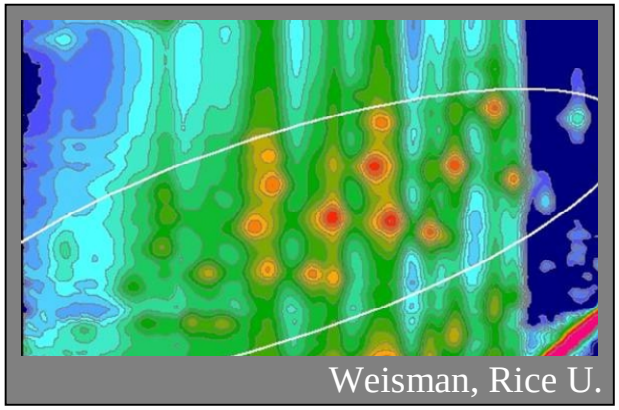



PRL **98**, 167406 (2007)

# PLE: family pattern

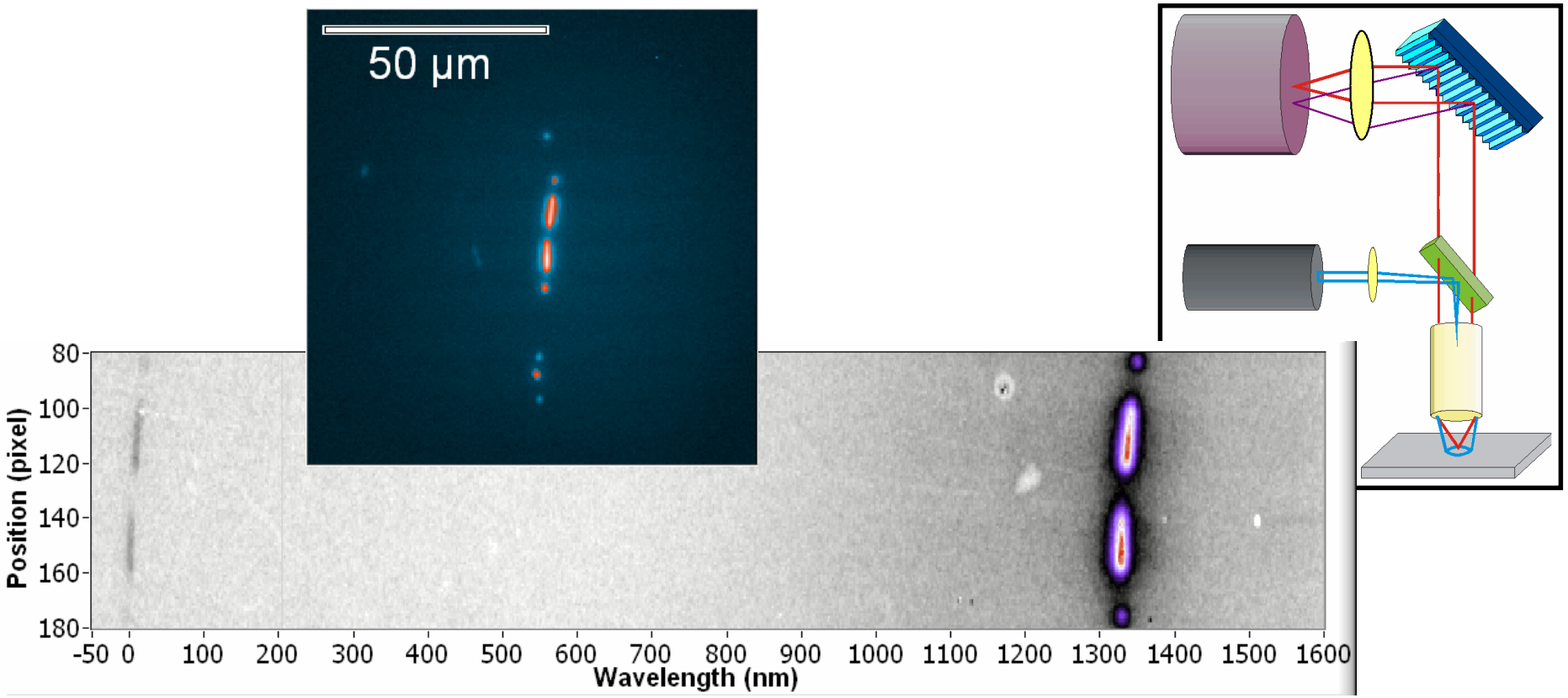
A family as defined by *2n+m*



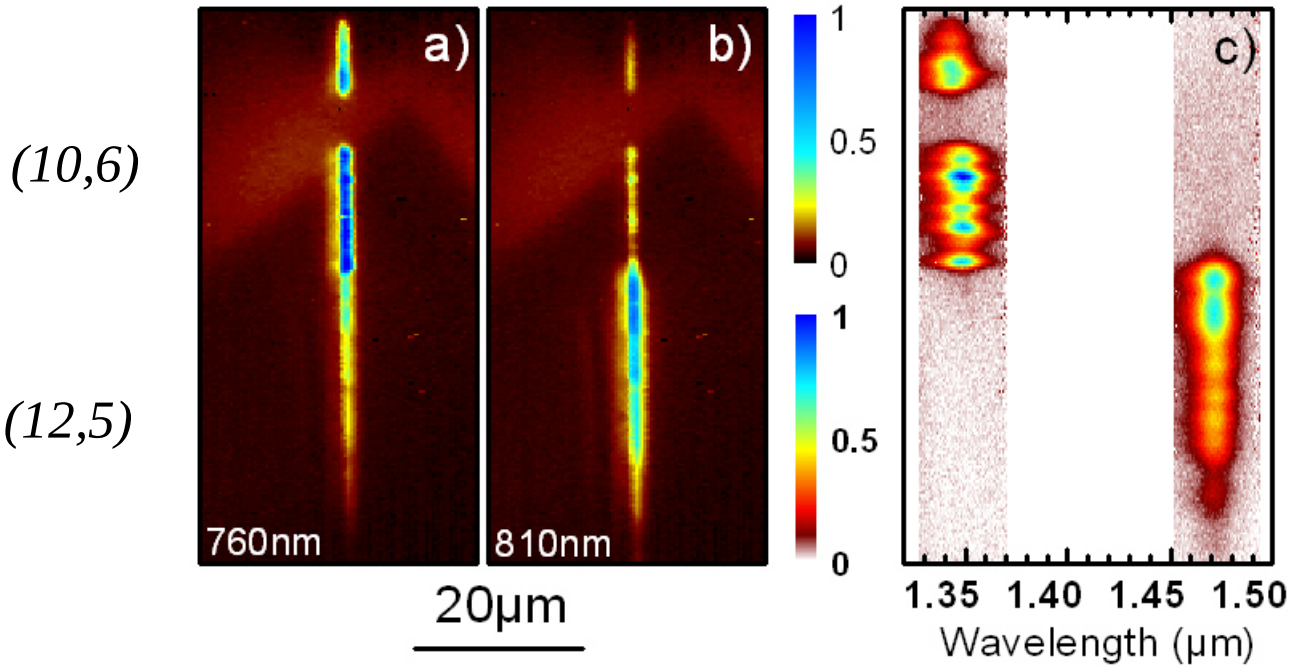




PRL **98**, 167406 (2007)

# PL imaging spectroscopy

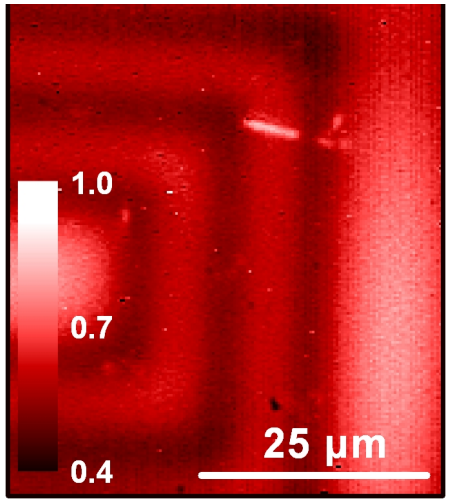


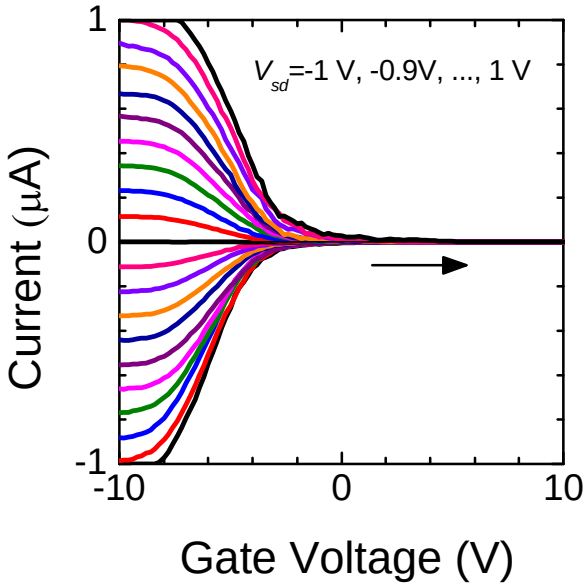
# Chirality change

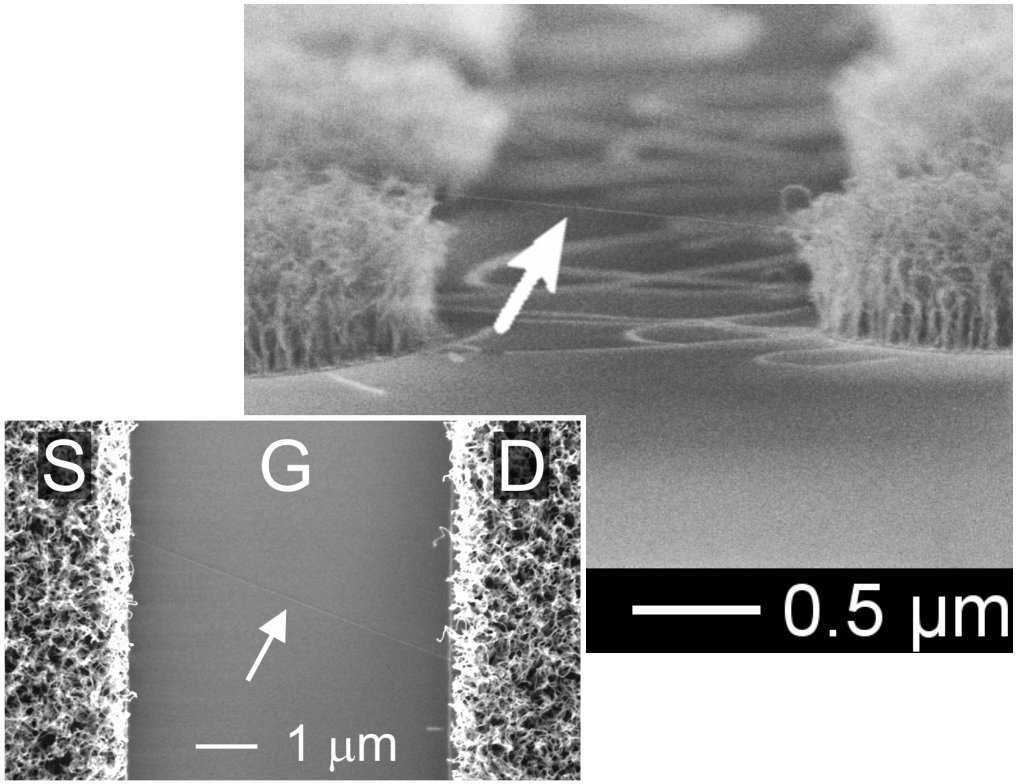



NanoLetters **6**, 1603 (2006)

# PL imaging of CNT-FET

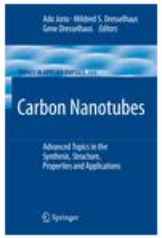



APL **90**, 103112 (2007)

# Publications

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- Lefebvre, Finnie Phys. Rev. Lett. **98** (2007) 167406
- Kaminska *et al.* Nanotechnology (2007) **18** (2007) 165707
- Austing *et al.* Appl. Phys. Lett. **90** (2007) 1013112
- Bond *et al.* Nanotechnology **18** (2007) 135603
- Lefebvre *et al.* Nano Letters **6** (2006) 1603
- Kaminska *et al.* Phys. Rev. B **73** (2006) 235410
- Finnie *et al.* Carbon **44** (2006) 3199
- Finnie *et al.* Phys. Rev. Lett. **94** (2005) 247401
- Lefebvre *et al.* Phys. Rev. B **70** (2004) 045419
- Lefebvre *et al.* Appl. Phys. A: Mater. Sci. **78** (2004) 1107
- Finnie *et al.* J. Vac. Sci. Technol. A 22 (2004) 747
- Lefebvre *et al.* Phys. Rev. B **69** (2004) 075403
- Lefebvre *et al.* Phys. Rev. Lett. **90** (2003) 217401