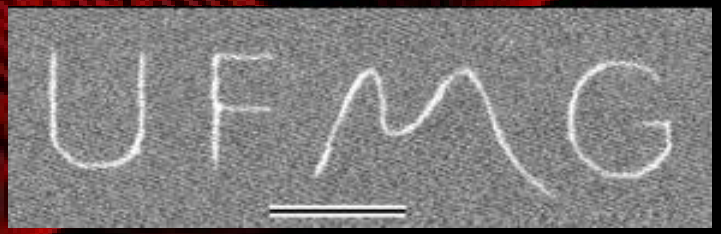
Research on Carbon Nanotubes in Belo Horizonte, Minas Gerais

Marcos A. Pimenta
Departamento de Física
Universidade Federal de Minas Gerais
mpimenta@fisica.ufmg.br



Synthesis (arc discharge and CVD): Luiz O. Ladeira, Rodrigo Lacerda, André Ferlauto, Sérgio de Oliveira (DF-UFMG)

Separation, purification and functionalization: Clascídia Furtado, Adelina Santos (CDTN-CNEN), Indhira Maciel, Flávio Plentz, Luiz Orlando Ladeira, André Ferlauto, Sérgio de Oliveira (DF-UFMG)

Raman Spectroscopy : Ado Jorio, Marcos Pimenta, Cristiano Fantini, Luiz Gustavo Cançado, Mauricio de Souza (DF-UFMG)

Photoluminescence: Flávio Plentz, Henrique Ribeiro (DF-UFMG)

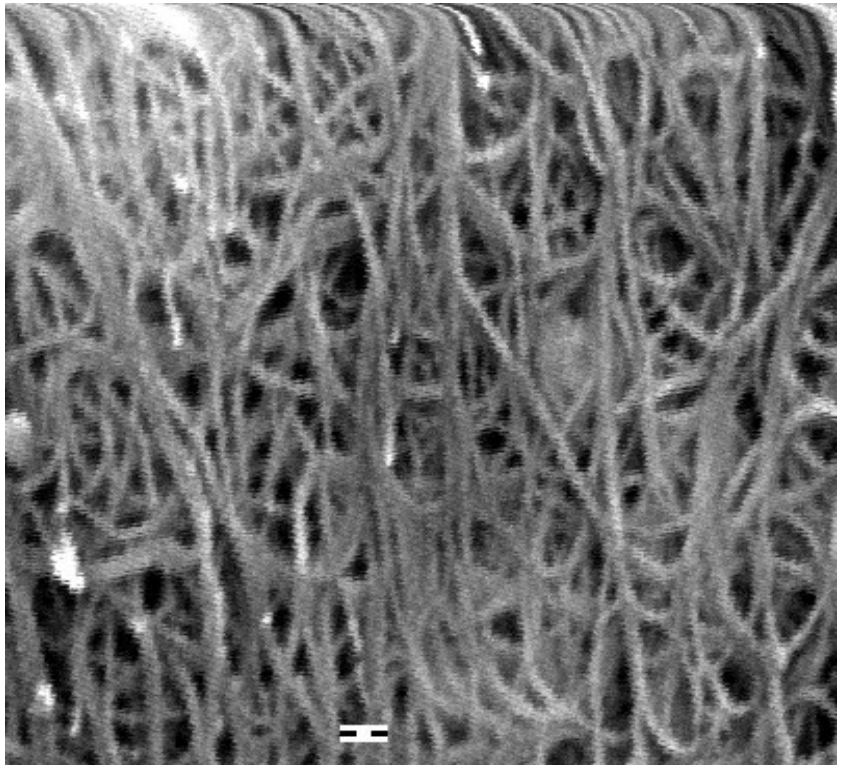
Theory and modelling: Hélio Chacham, Ricardo W. Nunes, Mário Sérgio Mazzoni (DF-UFMG)

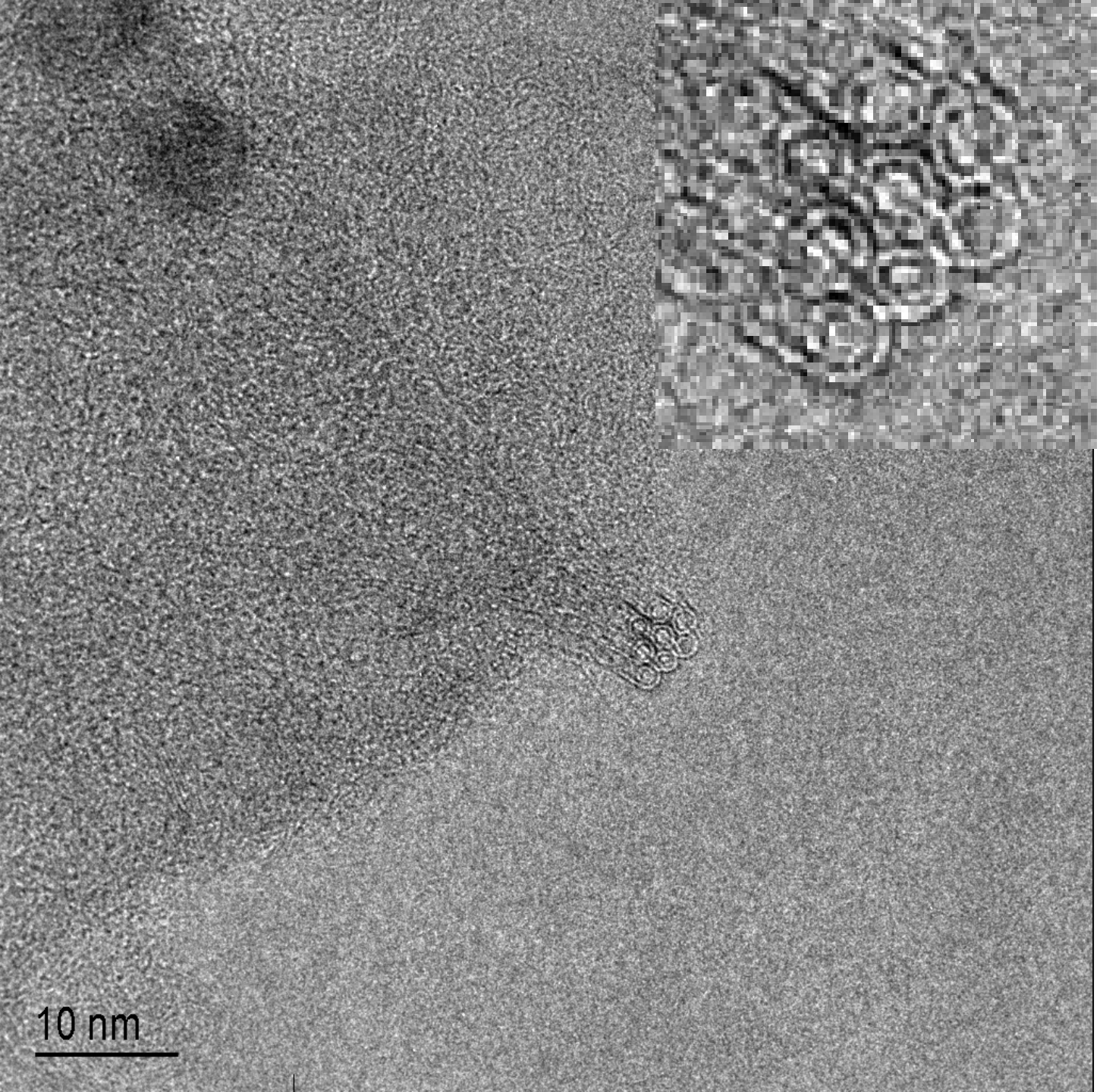
AFM and electronic microscopy: Bernardo Neves, Karla Balzuweit (DF-UFMG)

Collaborations

- Mildred Dresselhaus, Gene Dresselhaus, Georgii Samsonidze (MIT)
- Riichiro Saito (Tohoku University – Japan)
- Peter Eklund (Penn State University)
- Michael Strano (University of Illinois)
- Toshiaki Enoki (Tokyo Institute of Technology)
- Michel Callamé (Université de Basel, Suisse)
- Daniel Ugarte, Gilberto Medeiros-Ribeiro (LNLS, Brasil)
- Antônio G. Souza Filho (Universidade Federal do Ceará)
- Paola Corio (Universidade de São Paulo)

Bundles of carbon nanotubes produced by the electric arc method (since 2000)





Bunch of 8 single wall carbon nanotubes

K. Balzuweit,
L.O.Ladeira,
S. Oliveira

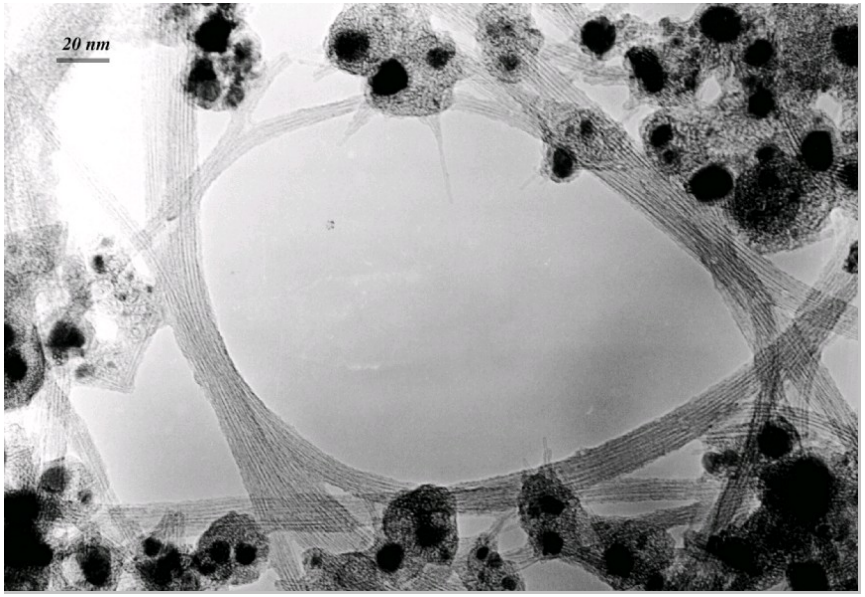
Physics Department
UFMG

The electron microscopy work has been performed with the JEM-3010 ARP microscope of LME/LNLS-Campinas.

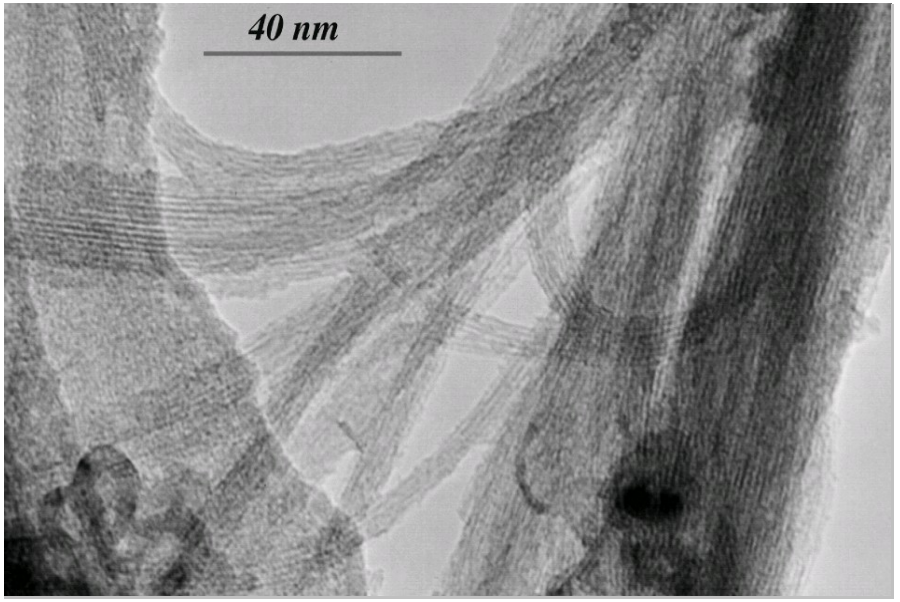
Purification of carbon nanotubes

Purification: the procedure should be optimized for each batch and it depends on the which functional groups are required and what the sample will be used for.

Before purification : 30% of nanotubes



After purification : 90% of nanotubes



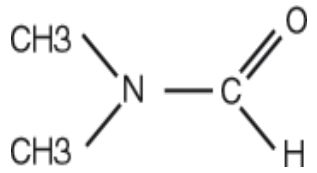
Dispersion and functionalization of carbon nanotubes

High polarizability of the nanotube wall

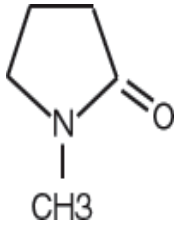
- ***van der Waals*** *interaction with high energy bond:*
~ 500 eV per μm of tube-tube contact

-***bundles*** *might contain hundreds of nanotubes bound together*

DMF

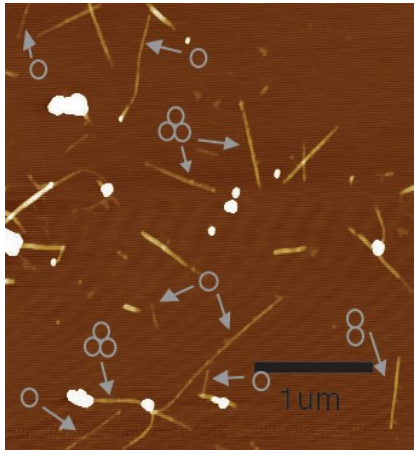


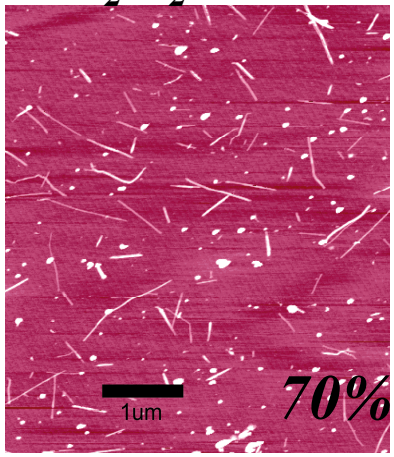
NMP

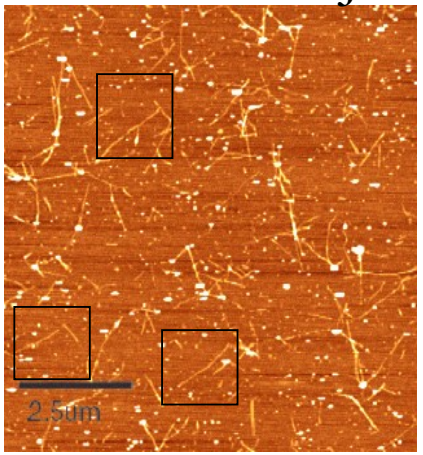


C. A. Furtado et al. JACS 126(19), 6095 (2004)

TT / HCl ***H_2O_2 / HCl*** ***TT / HNO_3***

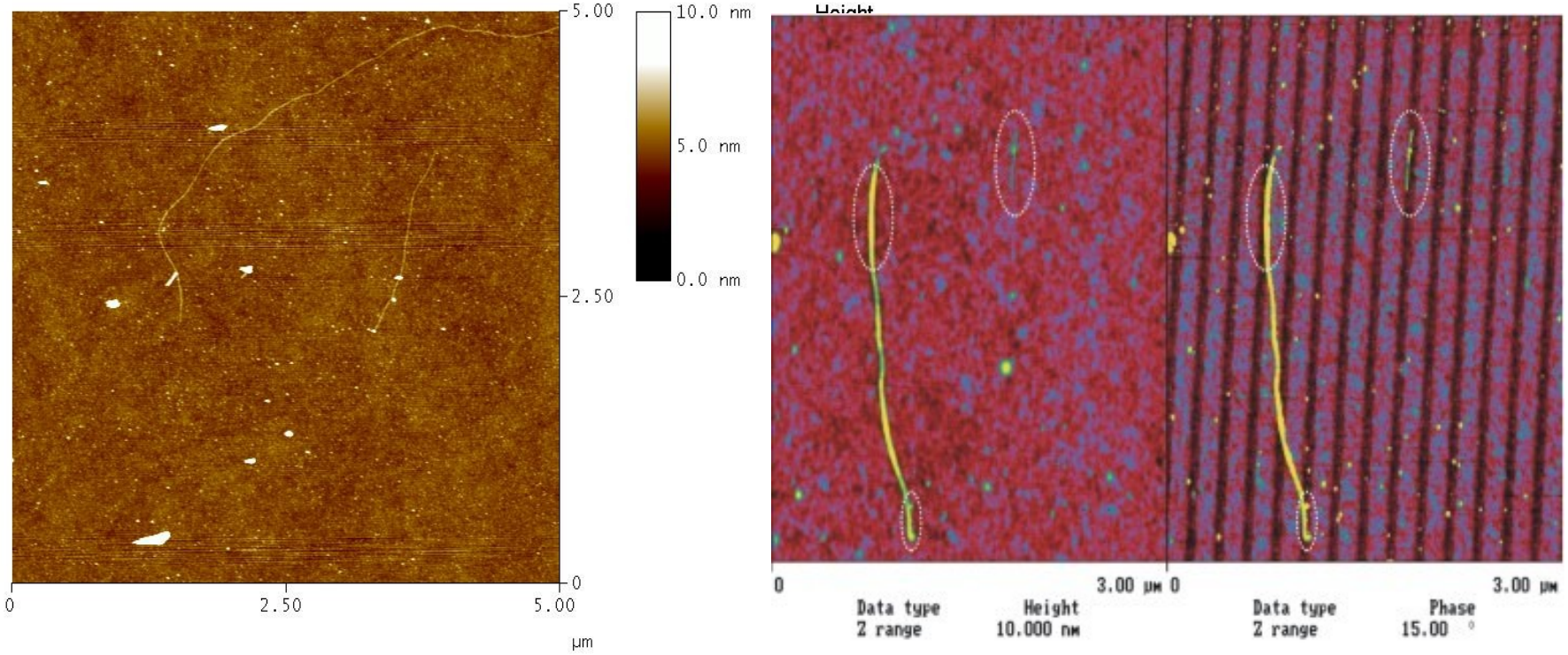




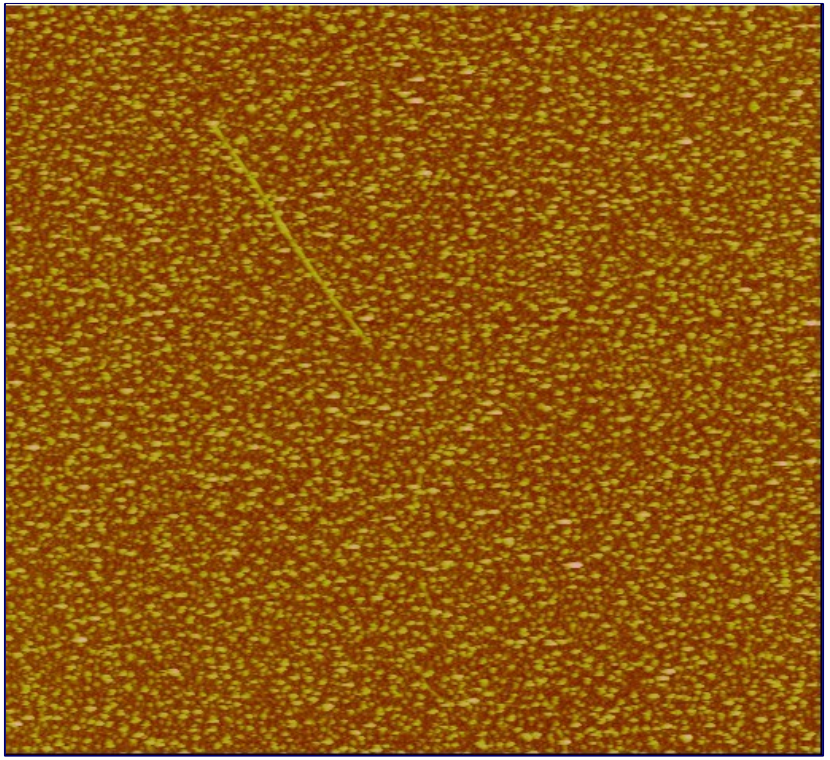


50% ***70%*** ***90%***

Separation and controlled deposition of carbon nanotubes in functionalized substrates

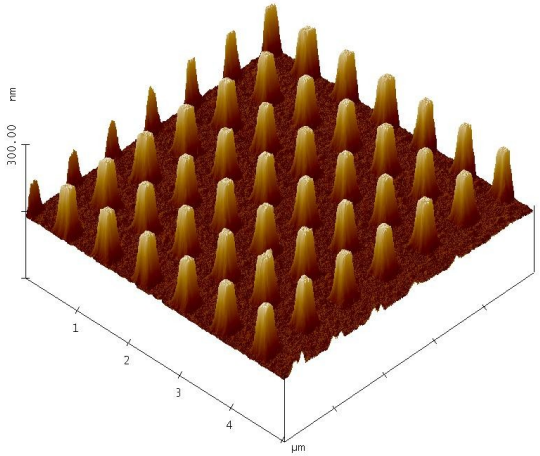


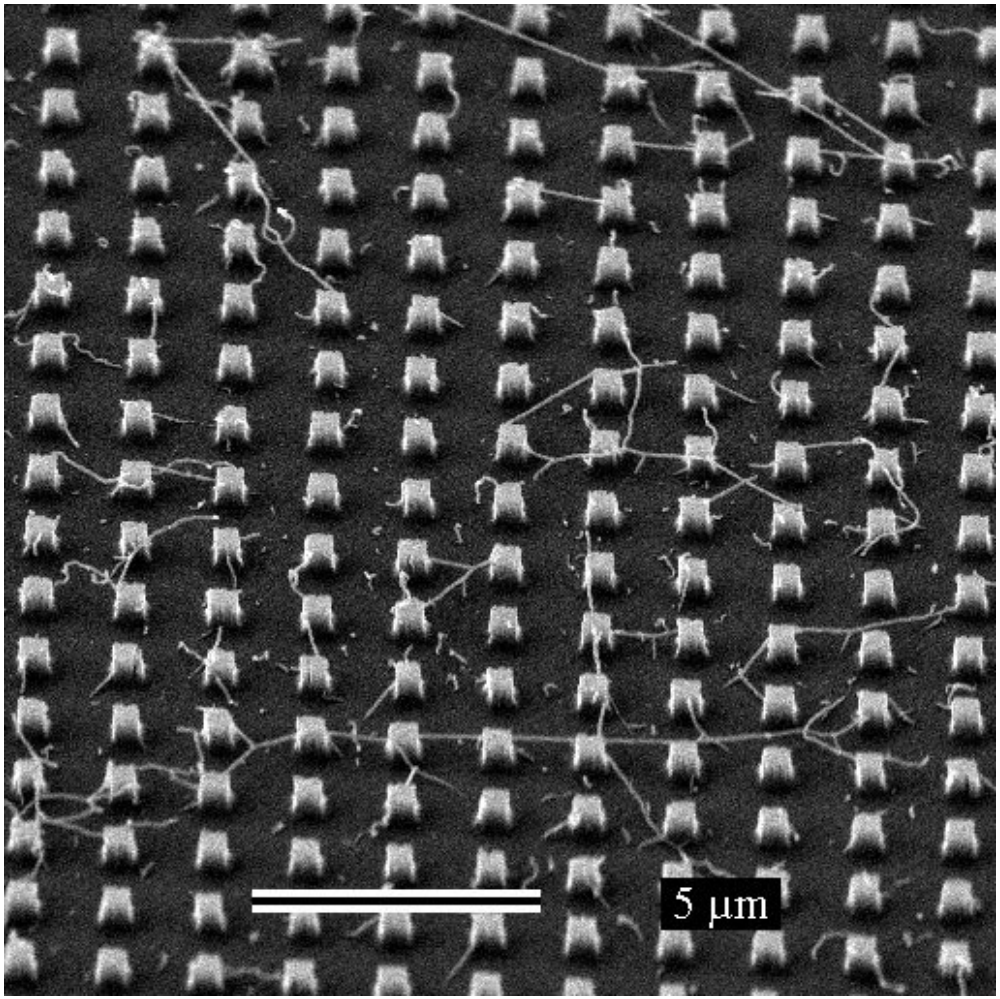
Synthesis of isolated carbon nanotubes by CVD



Synthesis of isolated carbon nanotubes suspended between pillars

RIE system for high definition corrosion



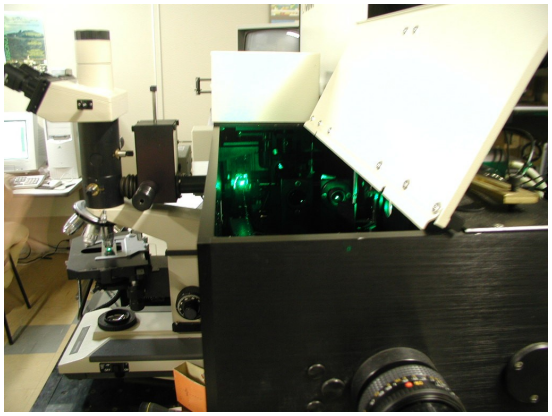


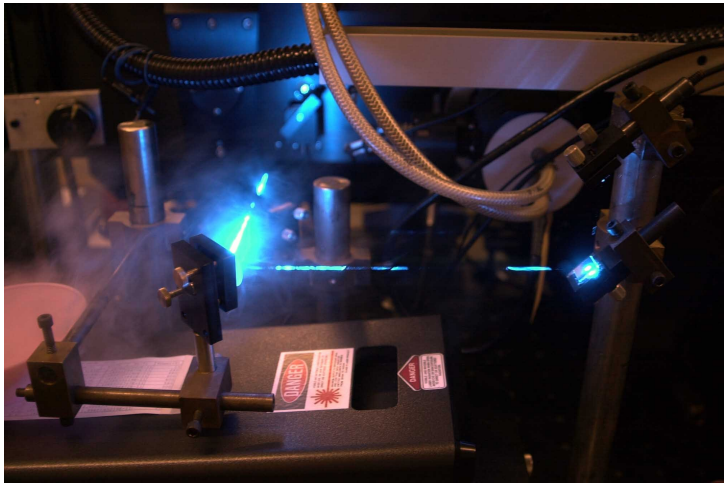
Resonant Raman Spectroscopy Laboratory, DF-UFMG

-Triple monochromator DILOR XY coupled to an optical microscope

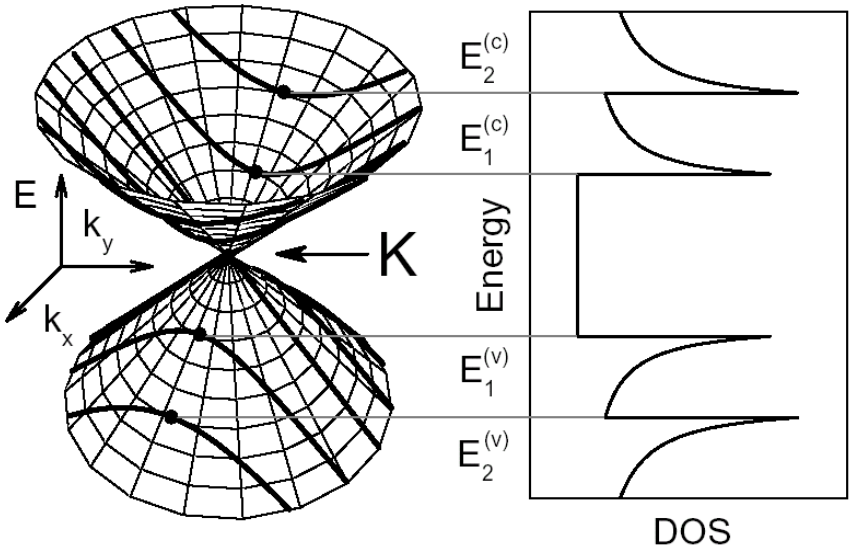
-Ar-Kr laser

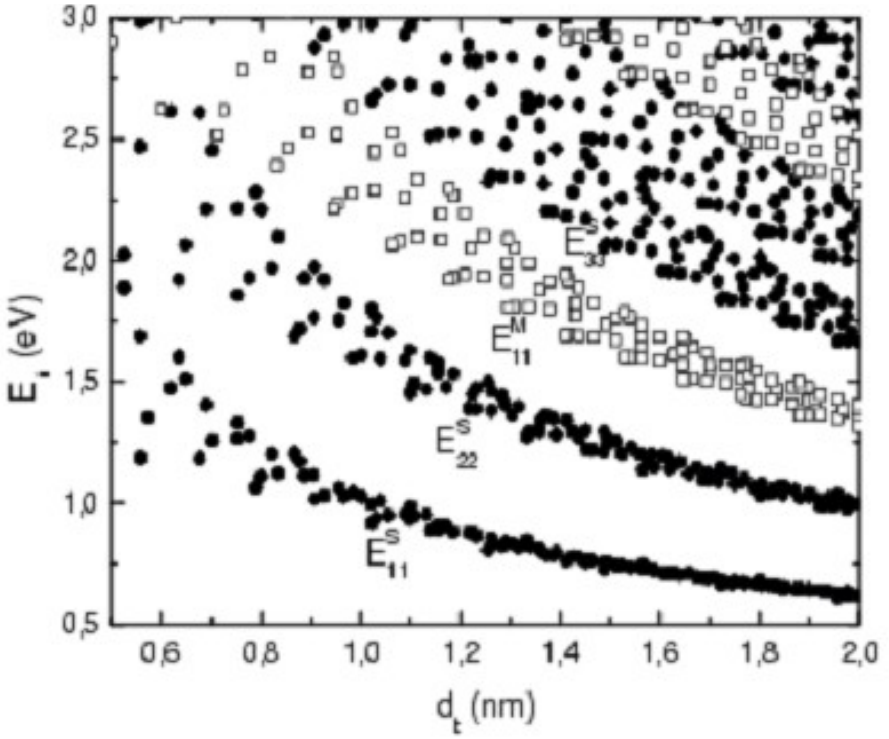
-Tunable laser systems (Dye- and Ti:Sapphire) pumped by an 9 W Ar laser



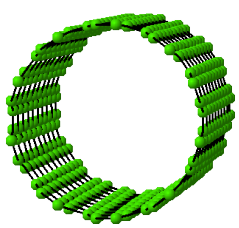


Van Hove singularitiesand optical transitions in carbon nanotubes

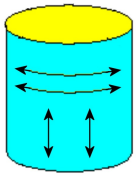




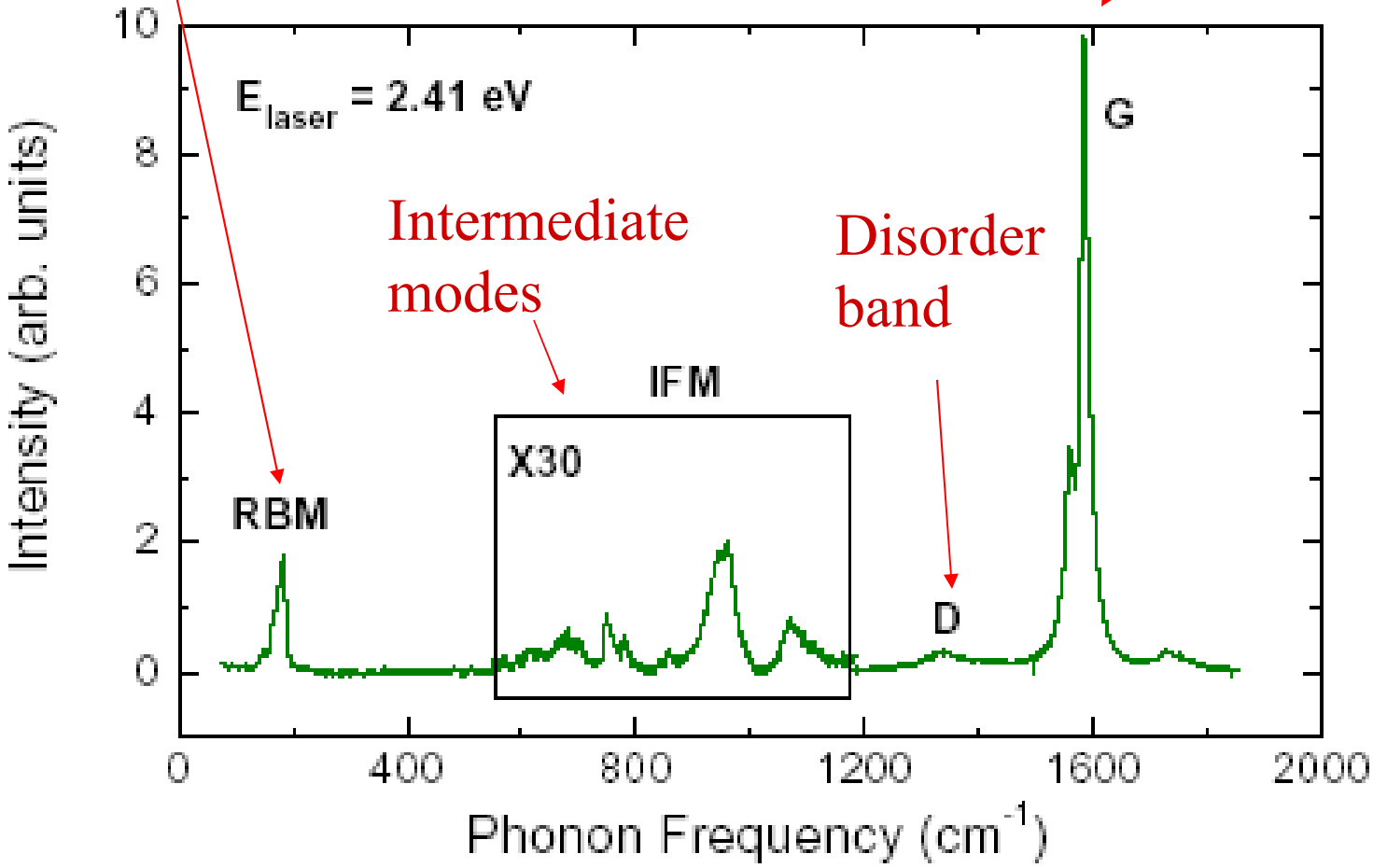
Raman spectrum of a carbon nanotube



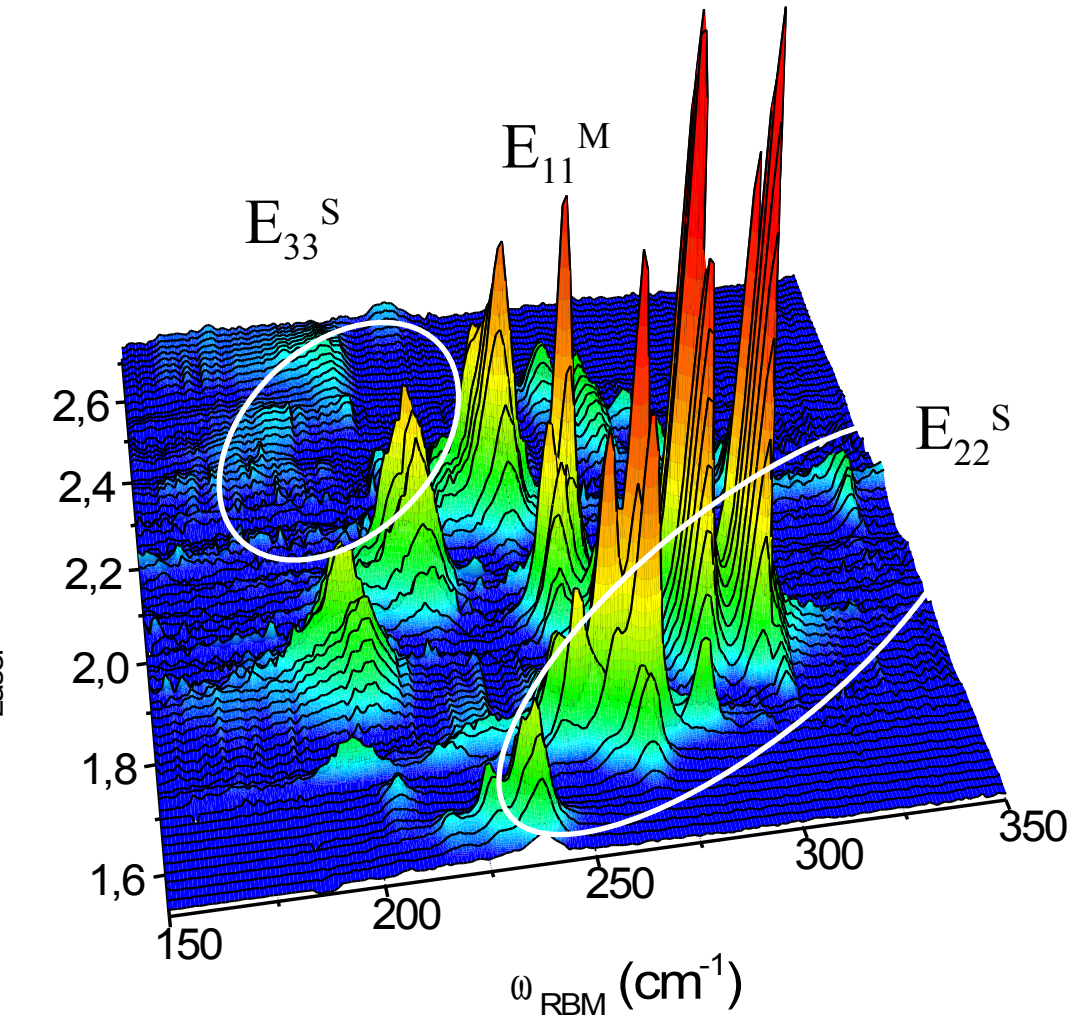
Radial breathing mode (RBM)

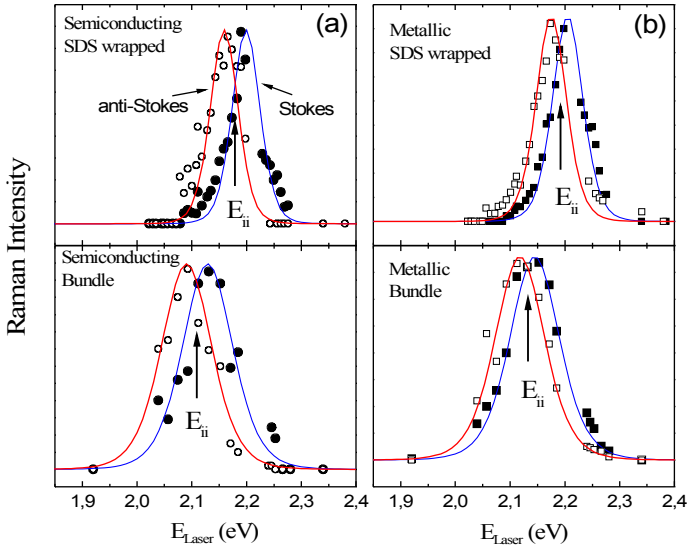


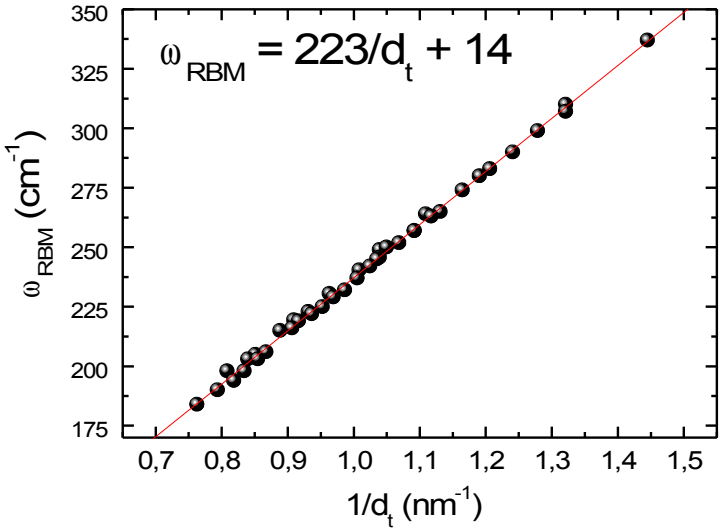
Tangential band G



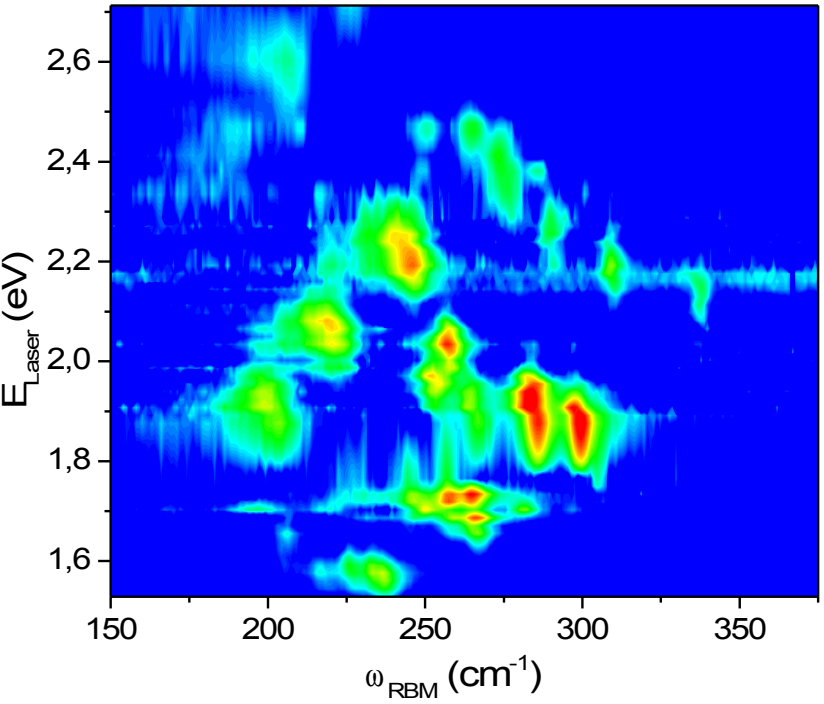
Reasonant Raman scattering of carbon nanotubes dissolved in water



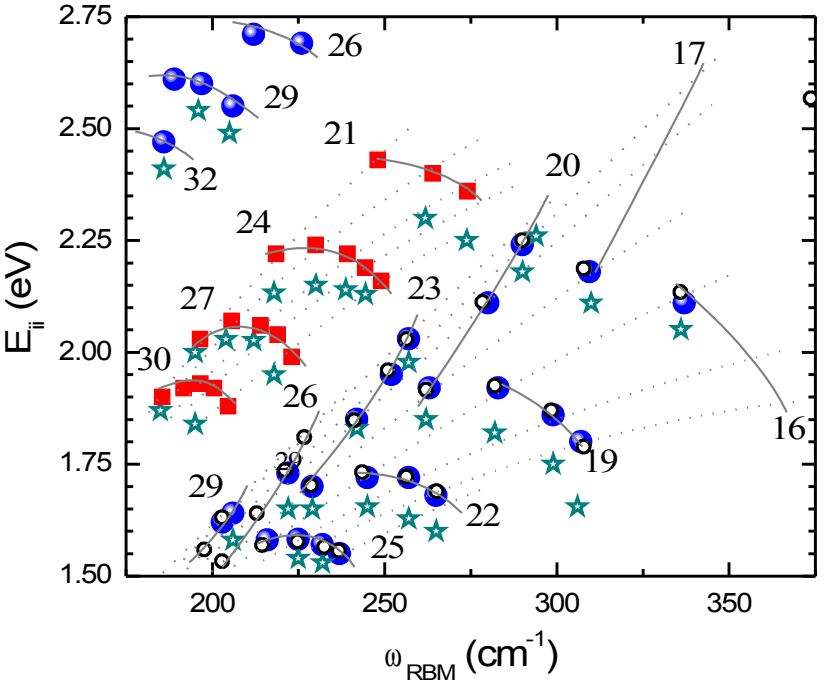


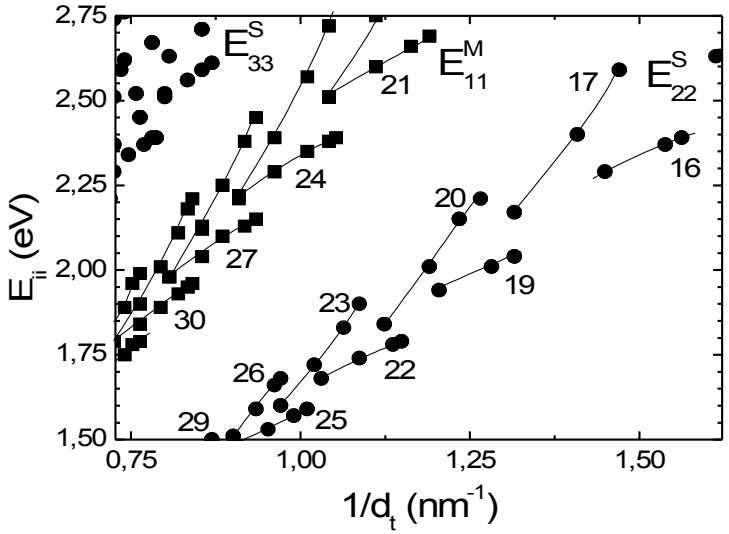


(n,m) structural characterization of a carbon nanotube



E_{ii}

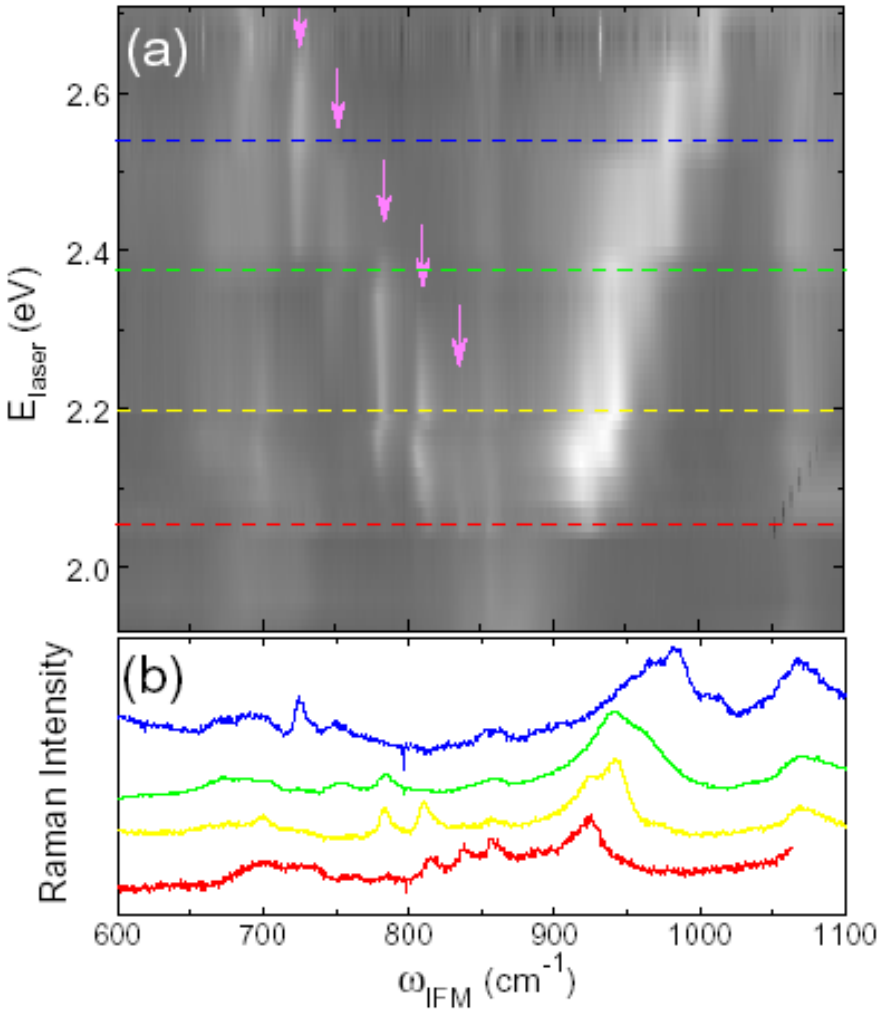


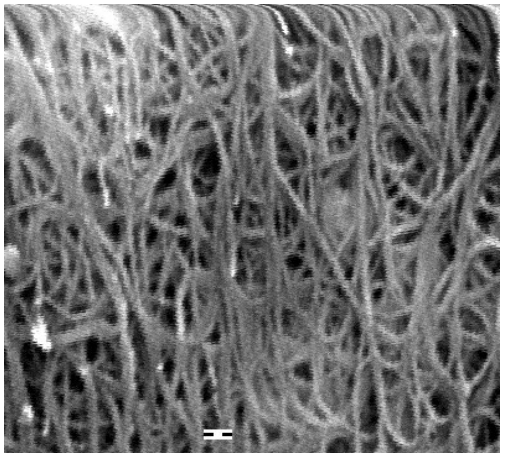


C. Fantini et al.,

Phys. Rev. Letters, 93, 147406 (2004)

Resonant Raman scattering of the intermediate frequency modes in carbon nanotubes





$$\omega^{+}_{IFM} = \omega_O + \omega_A = \omega_O + v_A\, q$$

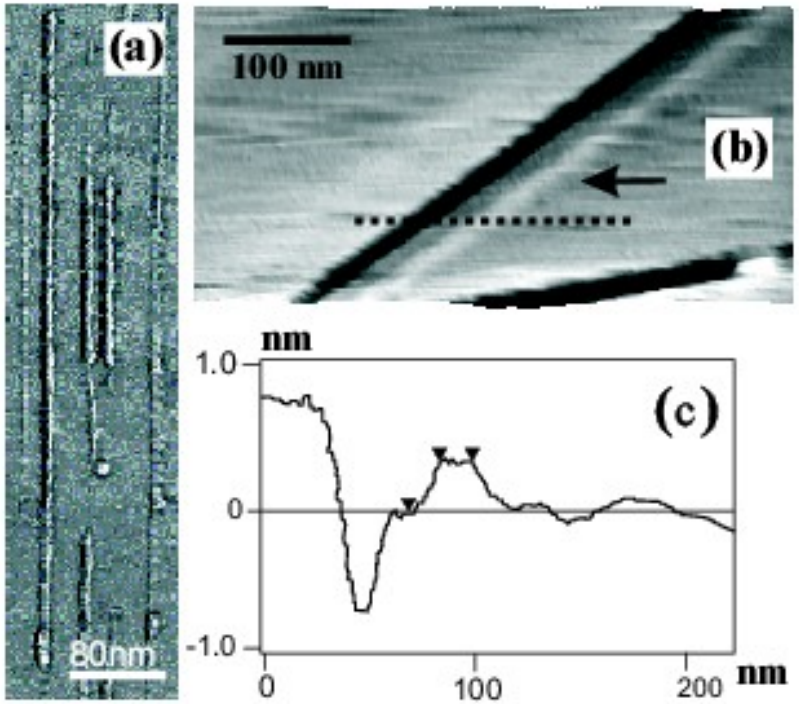
$$\omega^{-}_{IFM} = \omega_O - \omega_A = \omega_O - v_A\, q$$

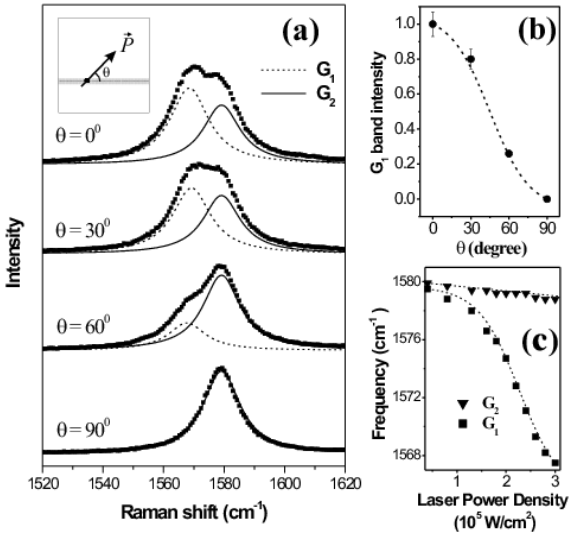
$v_A = 2.2 \times 10^4$ m/s

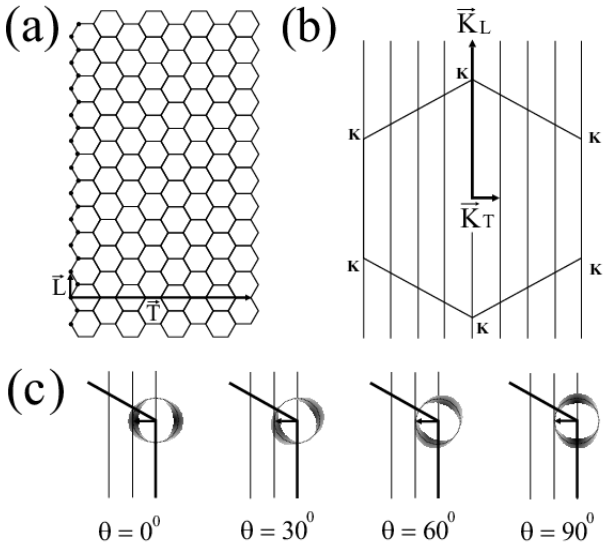
(sound velocity in graphite)

C. Fantini et al., Phys. Rev. Letters, vol. 93 (8), 087401 (2004)

Raman scattering in graphite nanoribbons



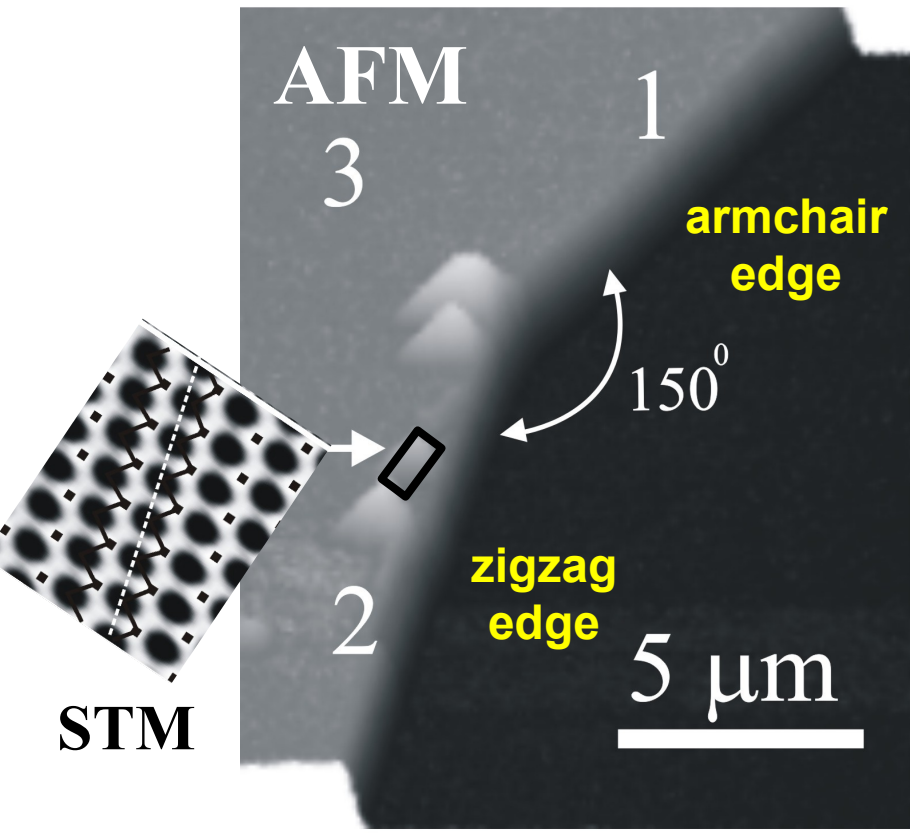


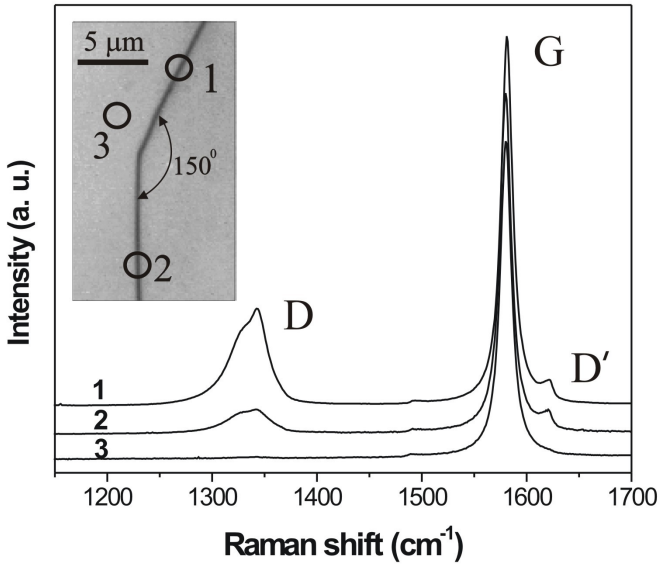


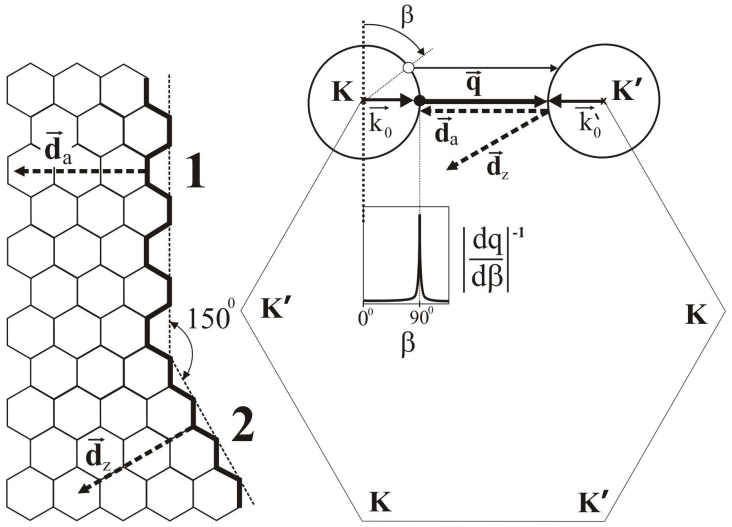
L. G. Cançado et al.,

Phys. Rev. Letters, vol. 93(4), 047403 (2004)

Raman scattering in graphite edges



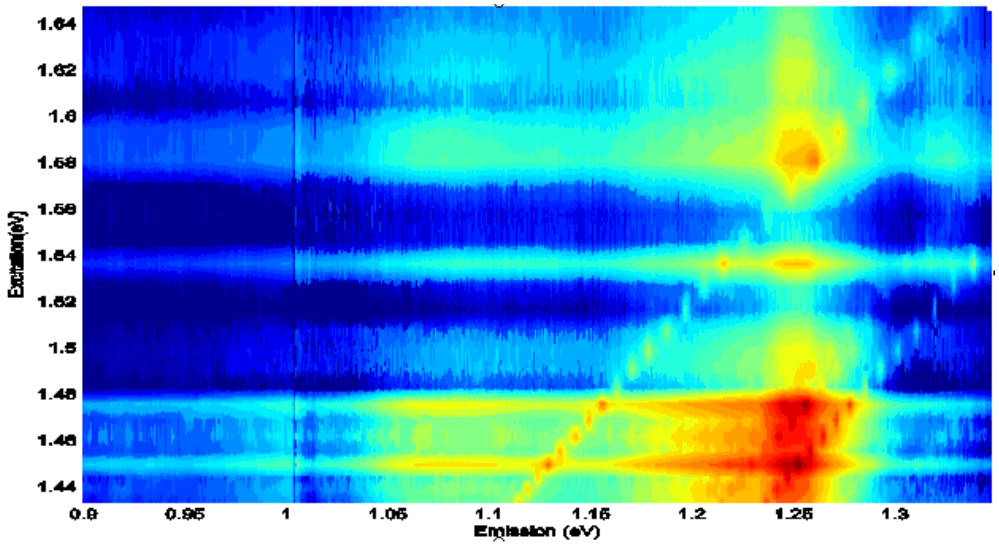




L. G. Cançado, M. A. Pimenta, B. R. A. Neves, M.S.S. Dantas , A. Jorio,

Phys. Rev. Letters, vol. 93, 247401 (2004)

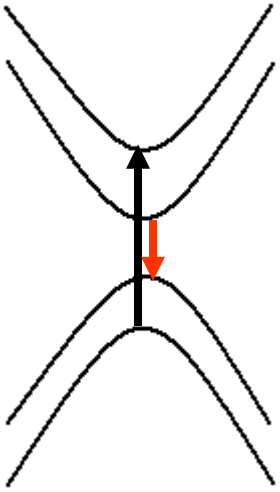
Photoluminescence of carbon nanotubes wrapped on DNA



S. G. Chou et al.,

submitted to Phys. Rev. Letters (2004)

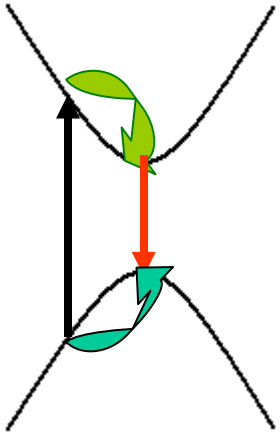
Electronic transition



$E_{ex} = E_{22}$

$E_{PL} = E_{11}$

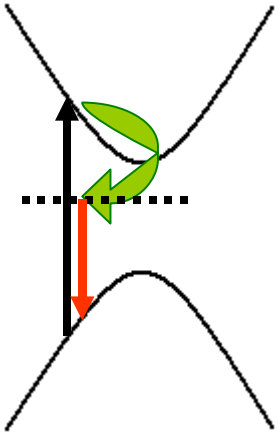
2-phonon jump



$E_{ex} = E_{11} - 2\hbar\omega$

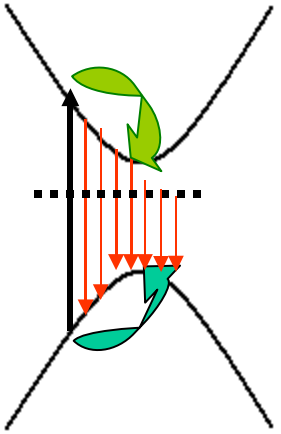
$E_{PL} = E_{11}$

Raman line



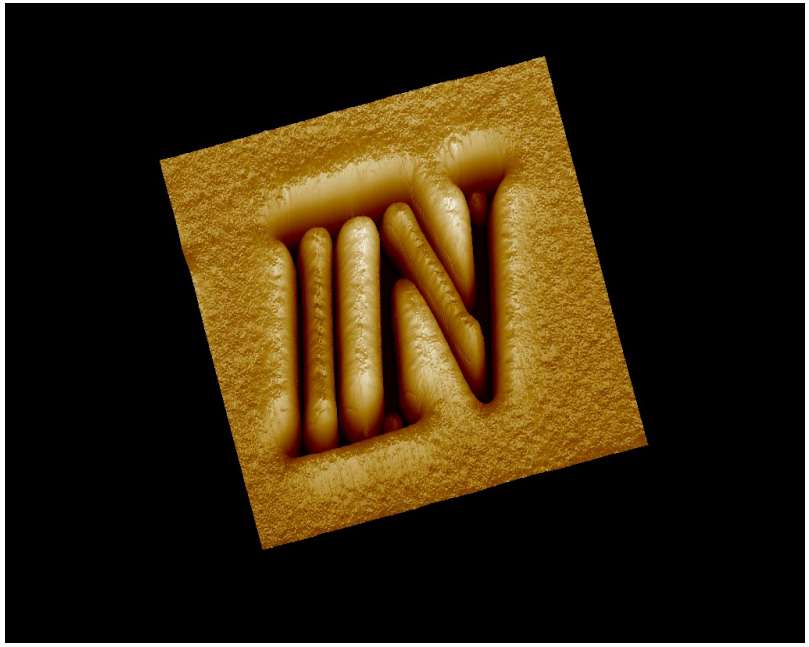
$E_{PL} = E_{ex} - \hbar\omega$

hot electron emission



$E_{ex} = C$

Acknowledgements



FAPEMIG
Fundação de Amparo à Pesquisa do Estado de Minas Gerais

UFMG

Instituto do Milenio de Nanociencias

Millenium Institute of Nanoscience

CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico