NSLS-II Workshop

March 15, 2004

Infrared Spectroscopy at the NSLS: from Solid State to Biomatter

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Laboratory of Nanostructures and Novel Electronic Materials

Ecole Polytechnique Fédérale de Lausanne

NN research group

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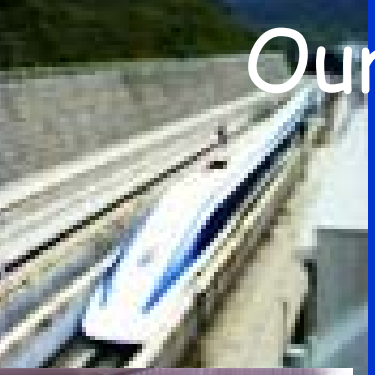
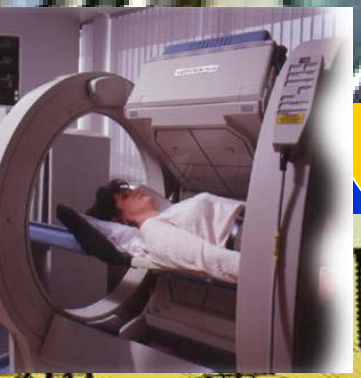
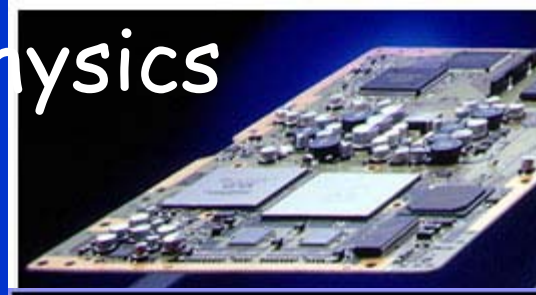
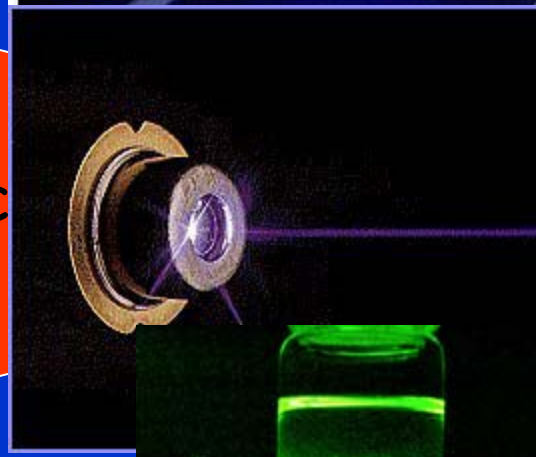
Our interest in solid state physics





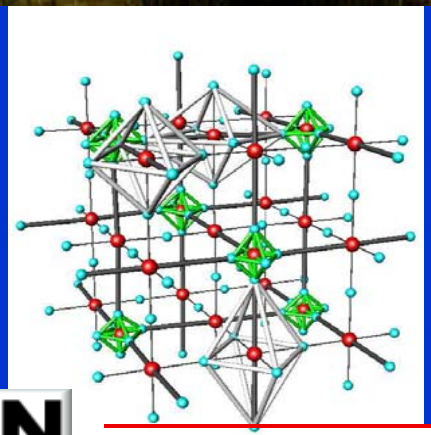


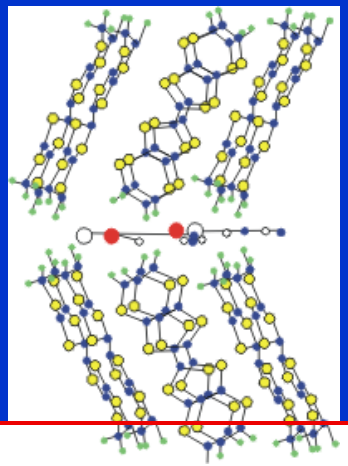


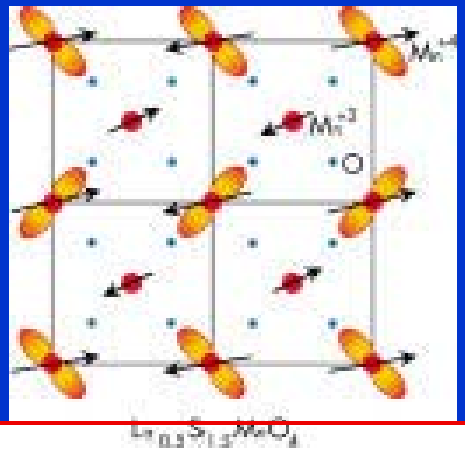
Metals

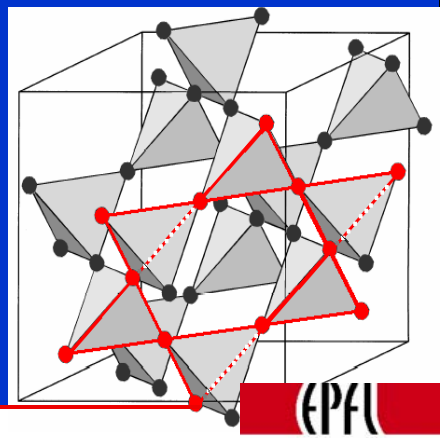
Semiconduc

Novel conductors, bad metals









NN research group

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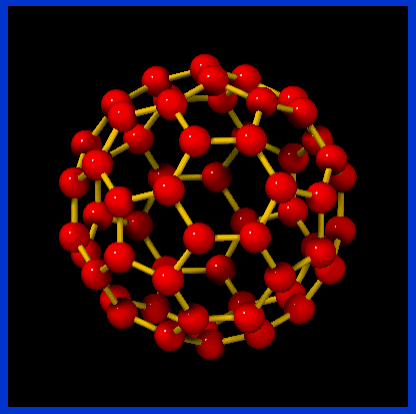
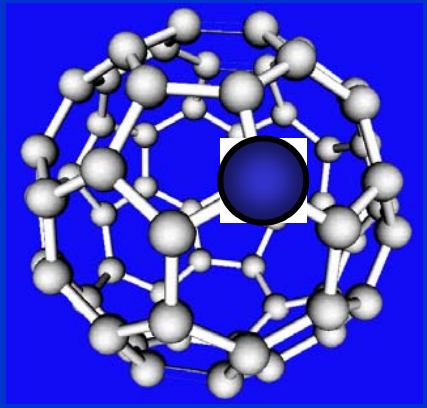
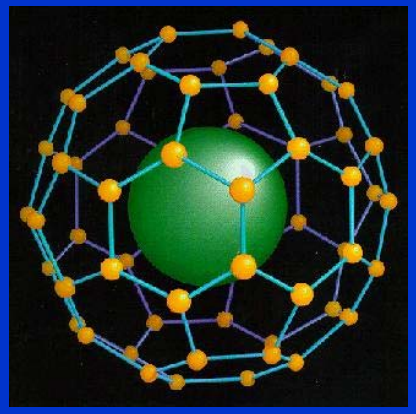
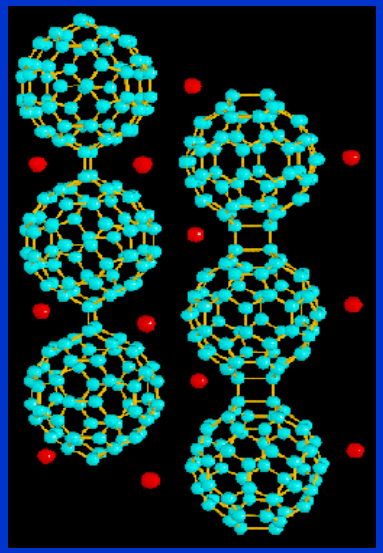
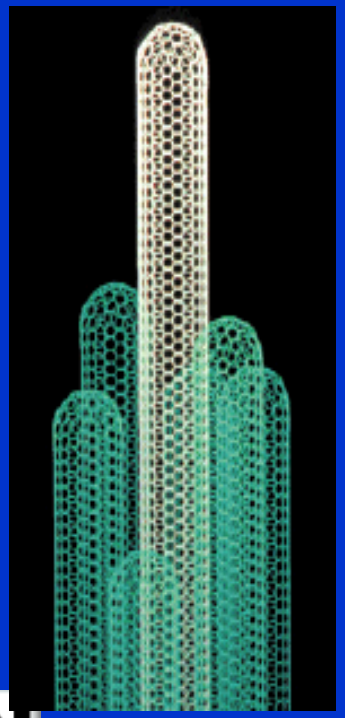
In Nanostructures

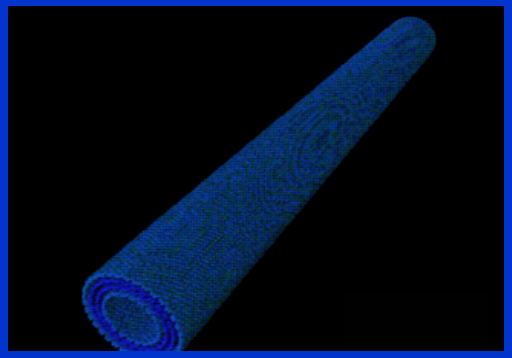


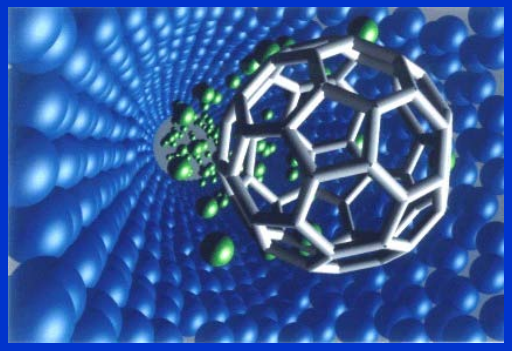


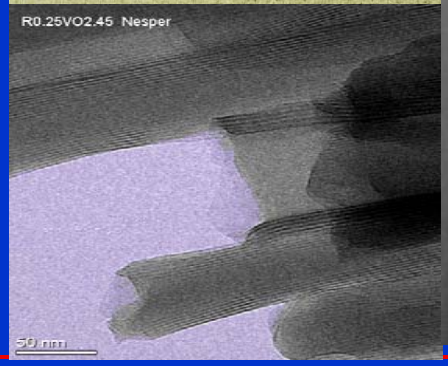


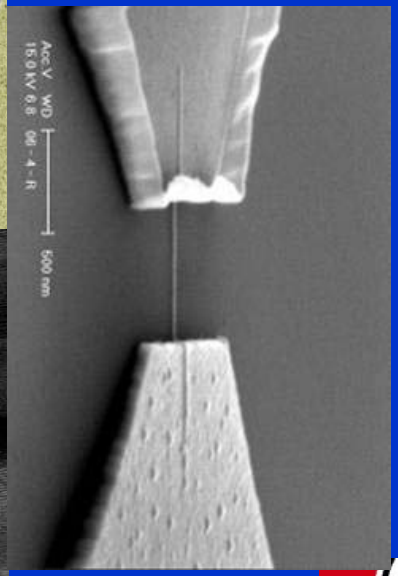






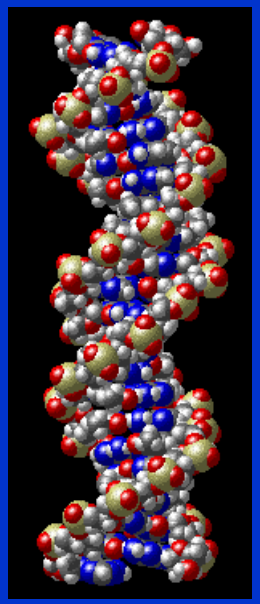




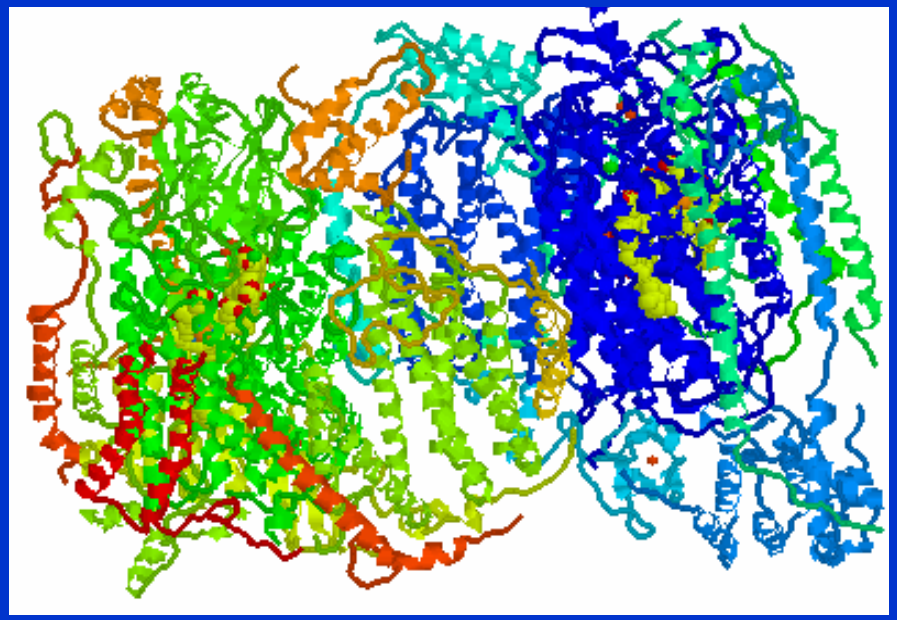


…and in Biomaterials

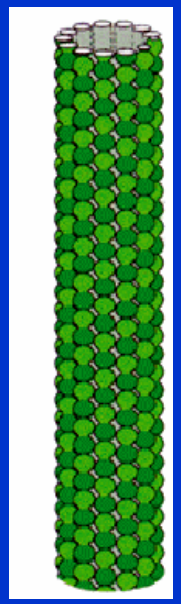
DNA



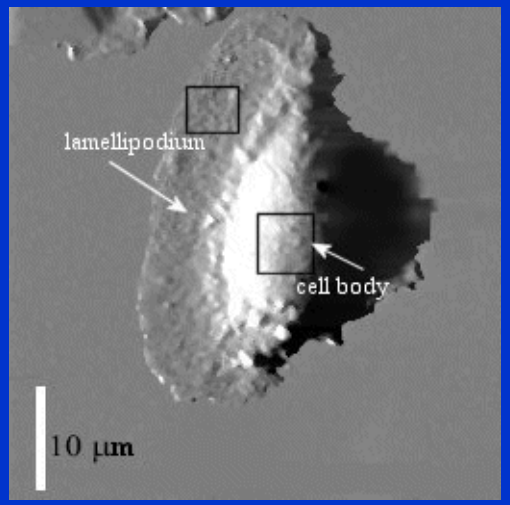
Protein

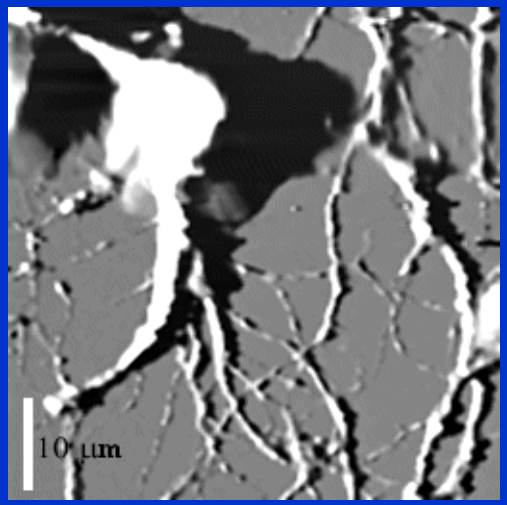


Protein polymer



Keratocyte



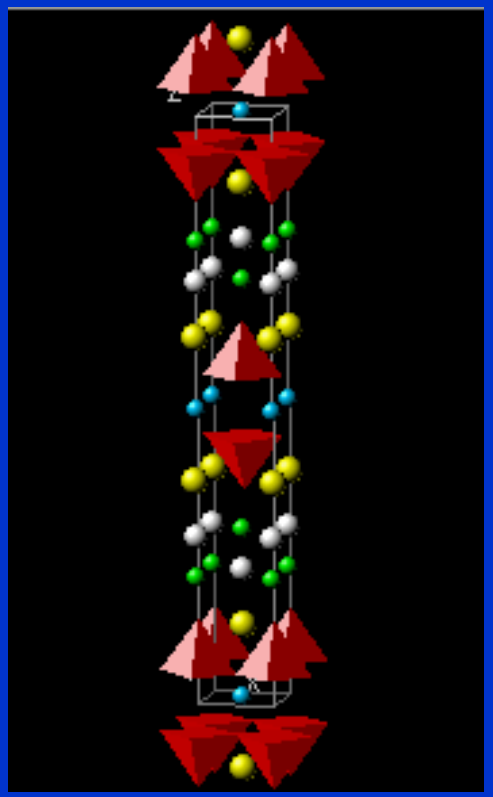


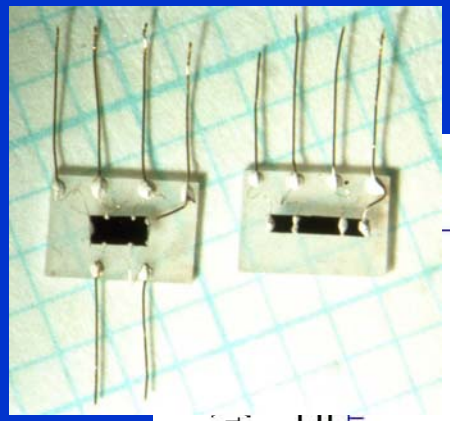
Neuron

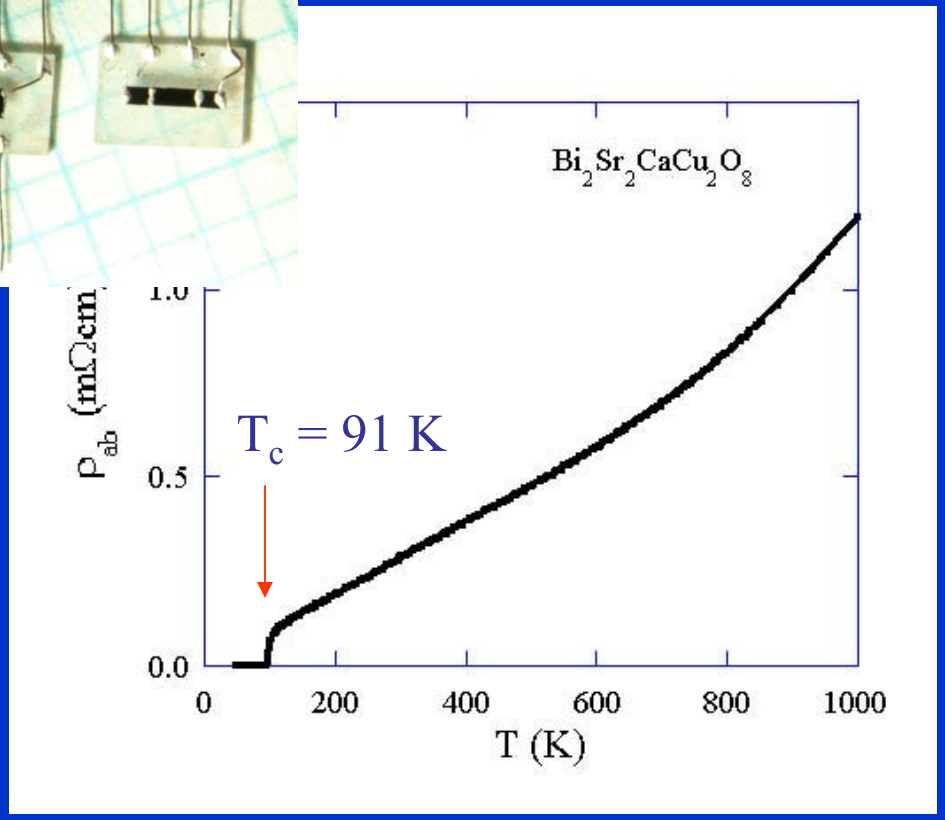
Solid State Physics

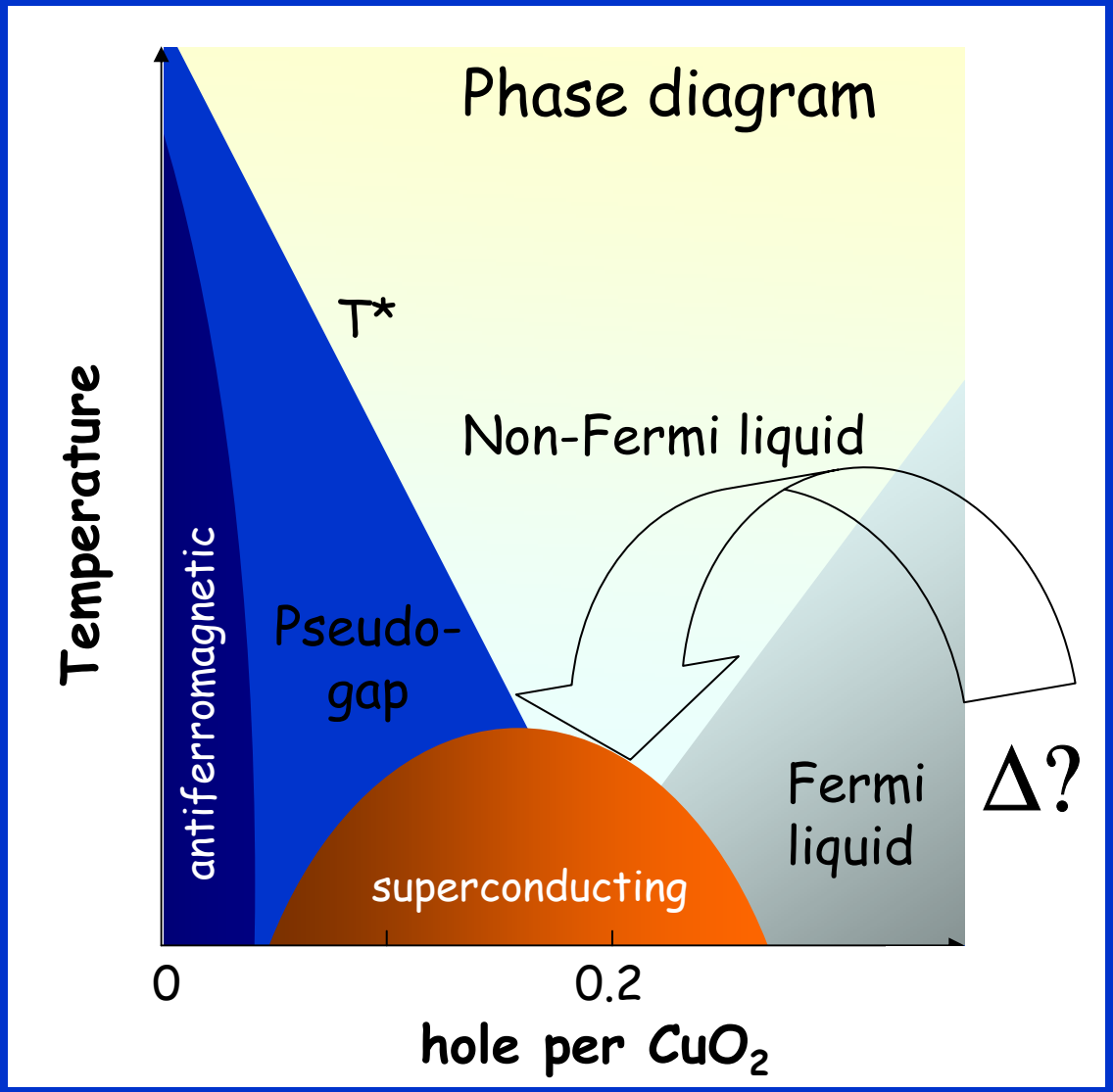
Studied at U4IR

High T_c sample: $Bi_2Sr_2CaCu_2O_8$









Goal: to study the superconducting gap

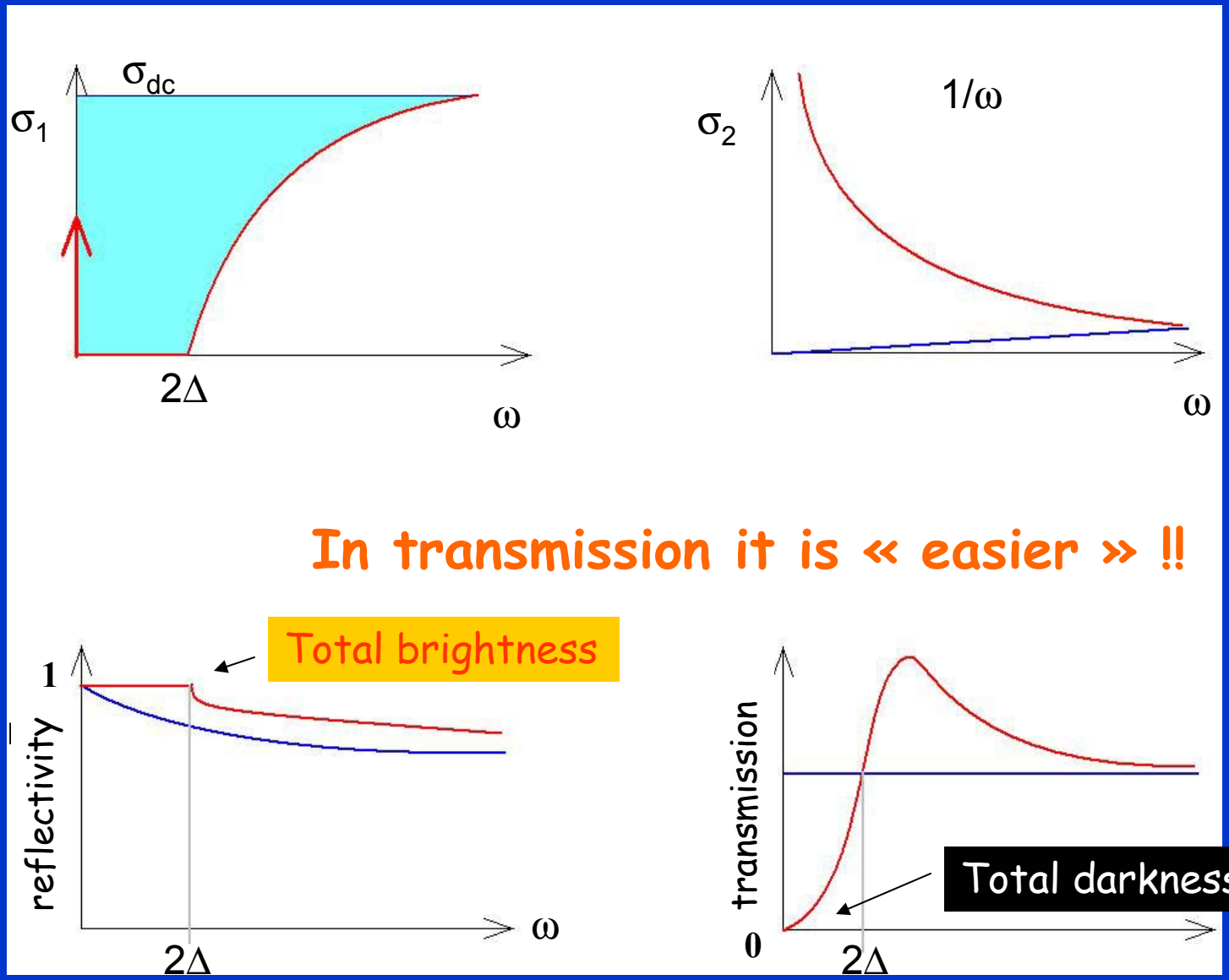
underdoped Optimally doped overdoped

How can we study Δ (at NSLS)?

- Electron in - electron out
  - EELS : SC → vacuum — keV
  - Tunnelling : SC → metal — meV
- Photon in - electron out
  - Photoemission — eV
- Electron in - photon out
  - Inverse Photoemission
- Photon in - photon out
  - Optical reflectivity
  - Optical transmission ← Our choice — meV
  - Raman scattering
- 300K = 25 meV = 200cm-1 = 6 THz
- Low Tc : 3.5x3K = 100 GHz — μwave
- High Tc : 3.5x100K = 230cm-1 FIR

Low T_c

$1/\tau \approx 10^{13}$ Hz, $2\Delta \approx 10^{10}$ Hz



PHYSICAL REVIEW VOLUME 108, NUMBER 2 OCTOBER 15, 1957

Conductivity of Superconducting Films for Photon Energies between 0.3 and $40kT_c$*

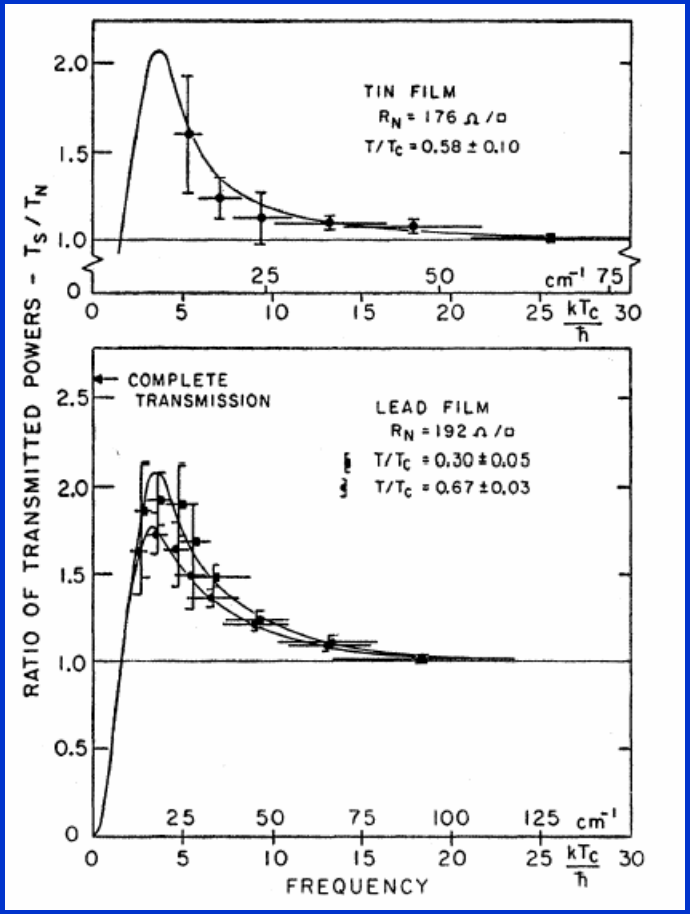
R. E. GLOVER, III,† *University of California, Berkeley, California and University of North Carolina, Chapel Hill, North Carolina*

AND

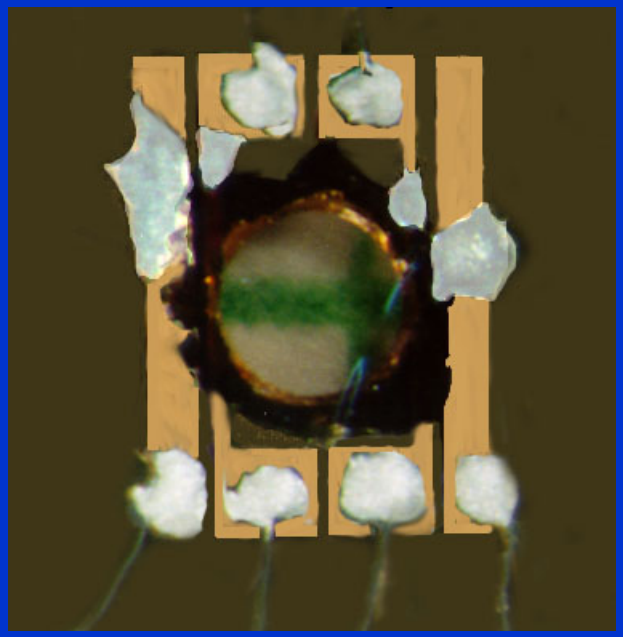
M. TINKHAM, *University of California, Berkeley, California*

(Received May 17, 1957)

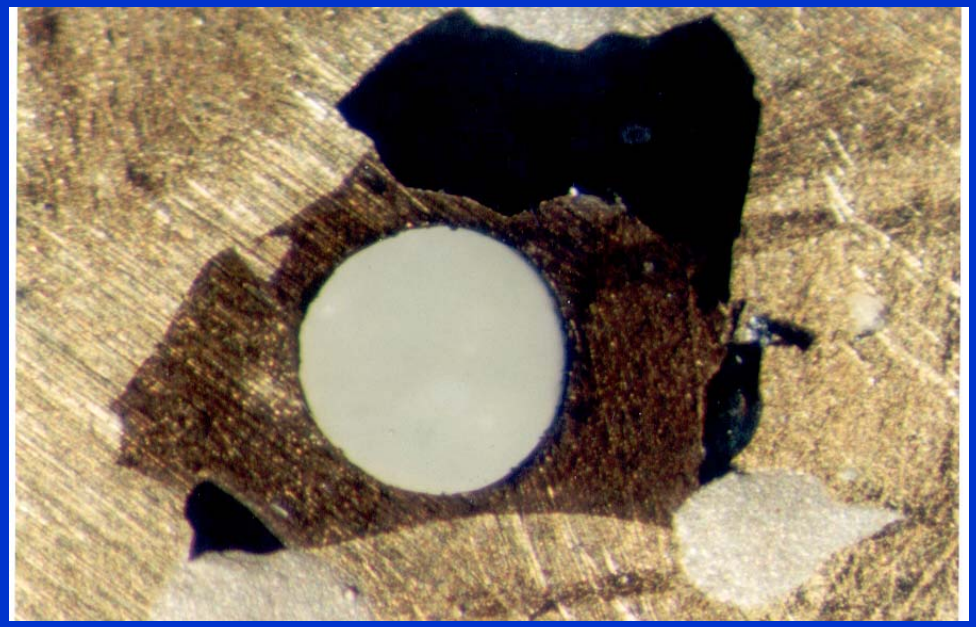
Reference paper!



Our method:transparent single crystals of $Bi_2Sr_2CaCu_2O_8$

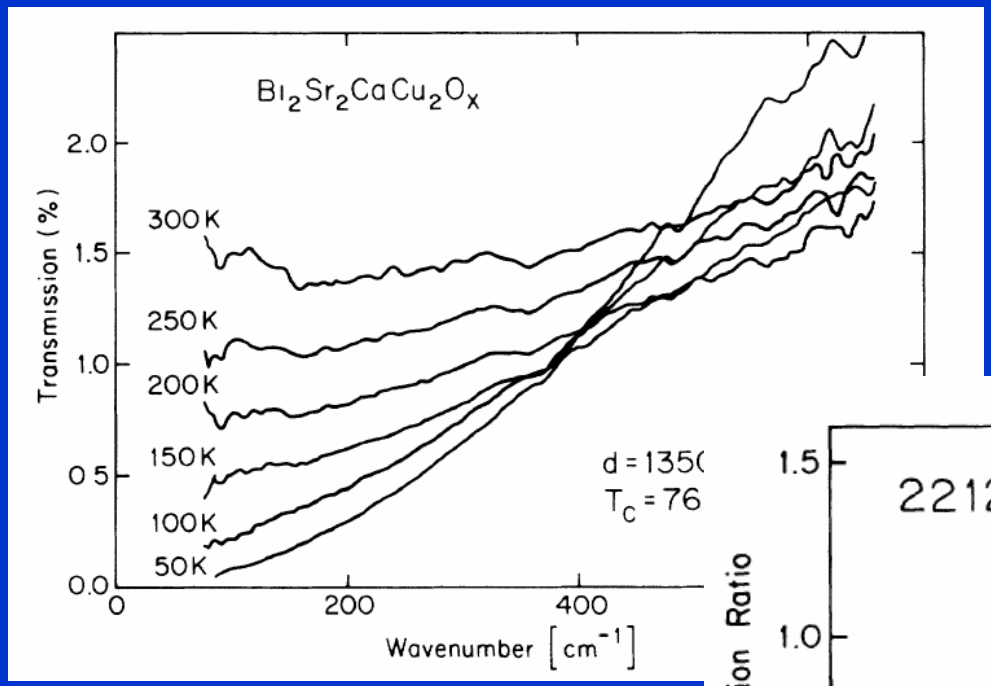


2212 150 nm thick single cystal, self-supported over 0.6 mm hole, contacted for resistivity, sapphire substrate

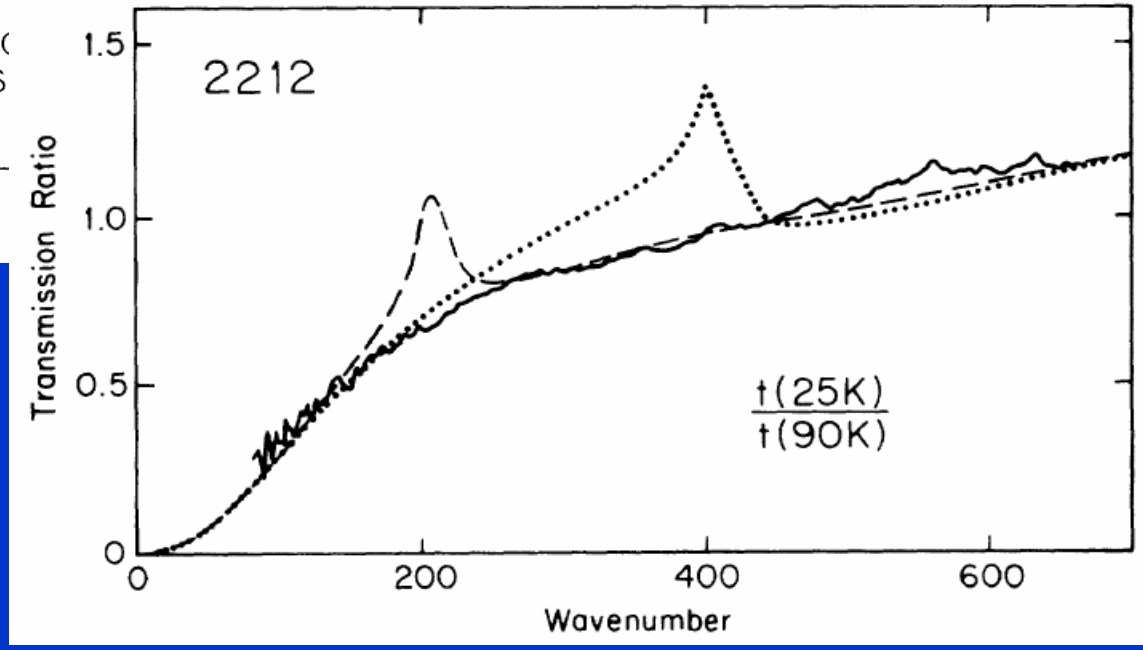


2212 100 nm thick single crystal, self-supported over 0.9 mm hole, platinum substrate

The first « good » results (from U4IR)

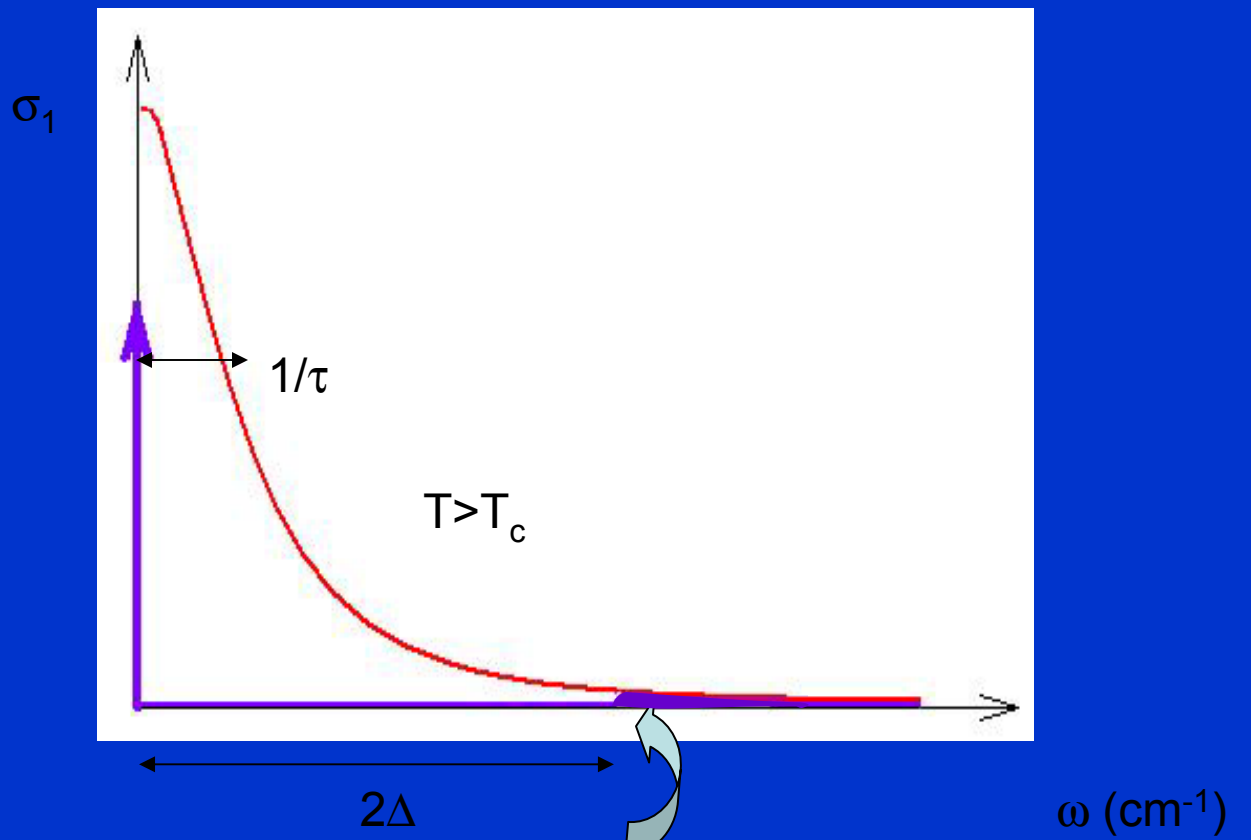


No peak in transmission ratios -> gapless superconductivity!



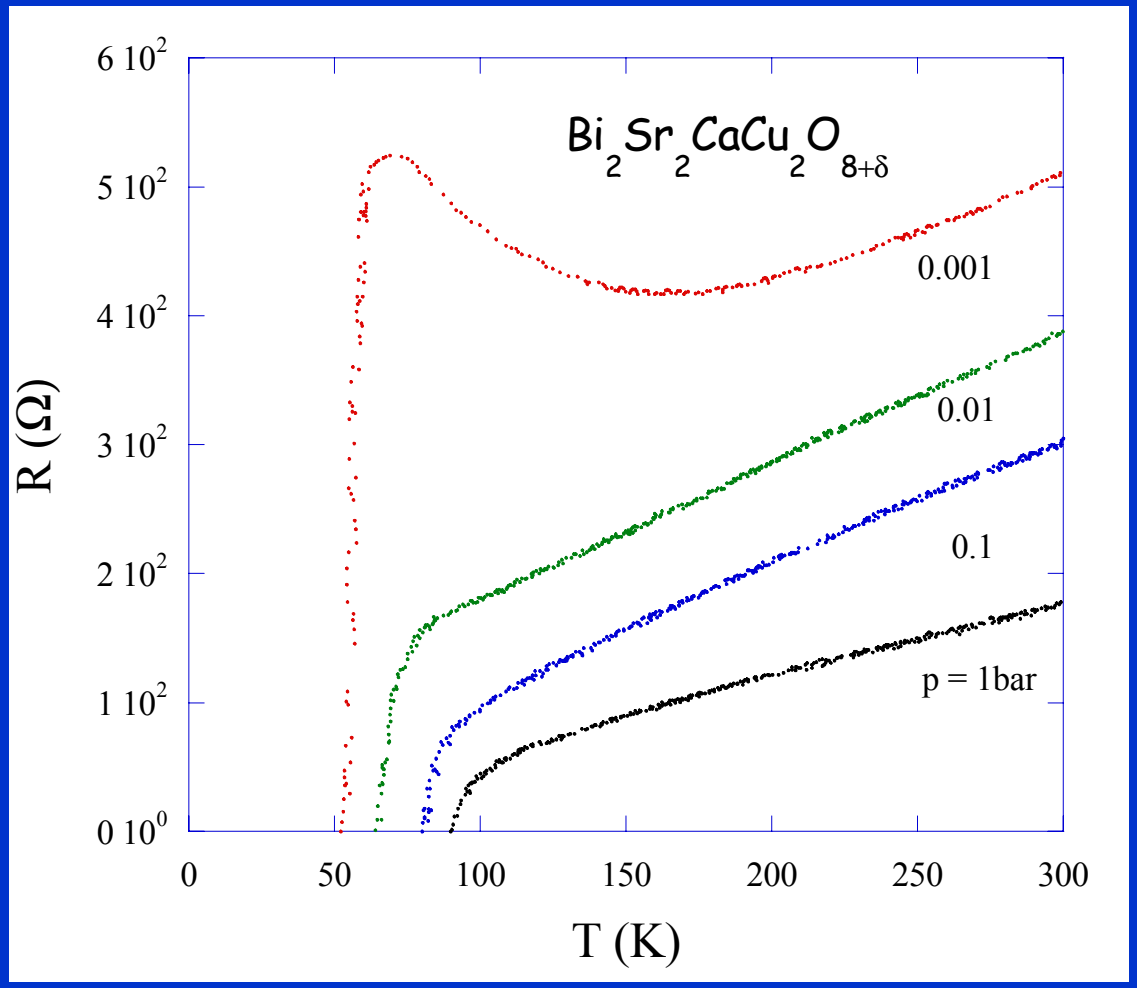
Forró et al., PRL, 65, 1941 (1990)

Counter-argument for the absence of the gap feature: Clean limit



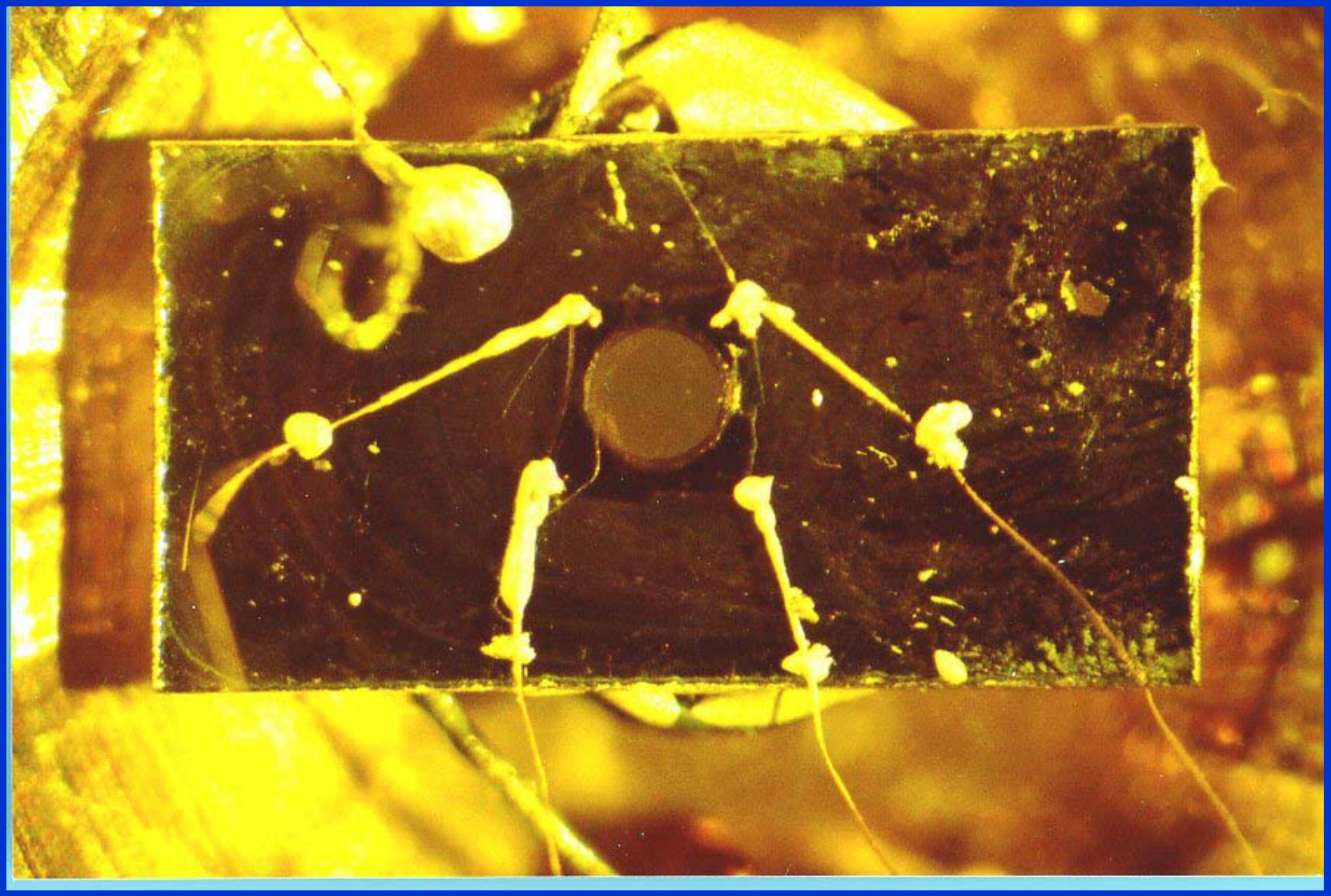
Very small oscillatory strength → Difficult to observe

Leaving the « clean limit » by introducing defects: by electron irradiation, off-stoichiometry, substitution

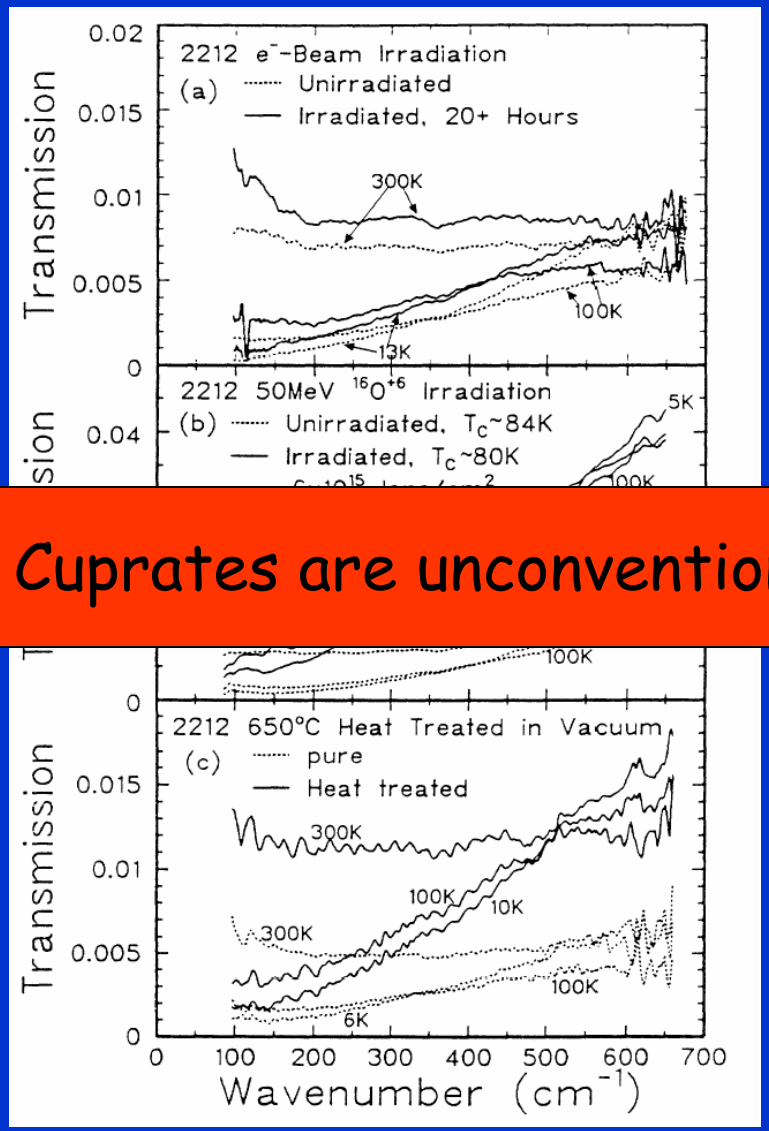


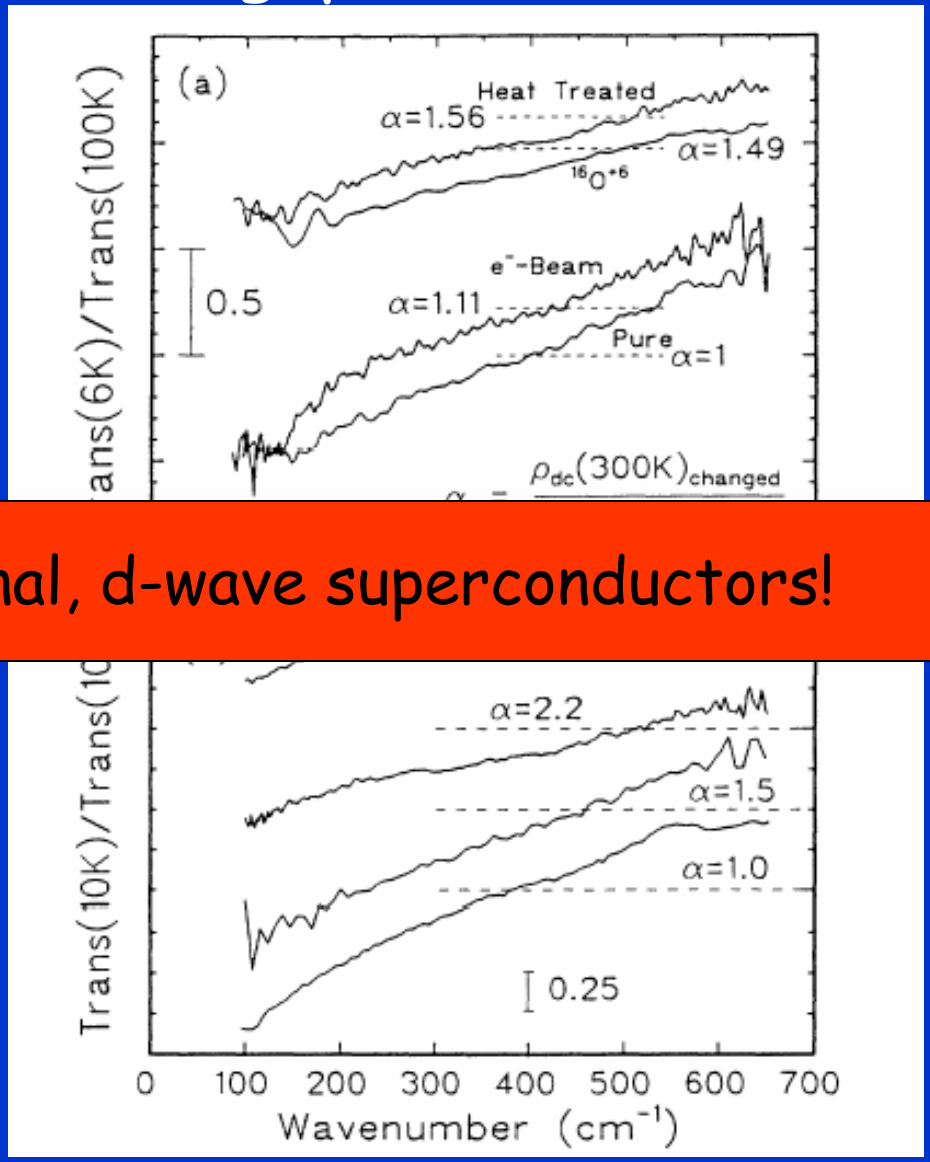
e.g.: by Oxygen depletion

Infrared transmission of 2212 up to high temperatures (500 °C) (U4IR)



Leaving « clean limit »:e-beam induced defects, heat treatment, substitution – still no gap feature!

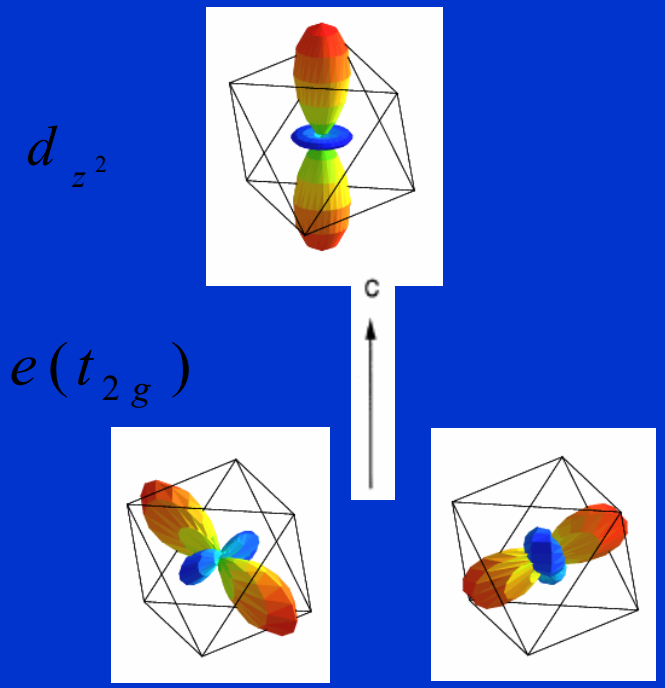


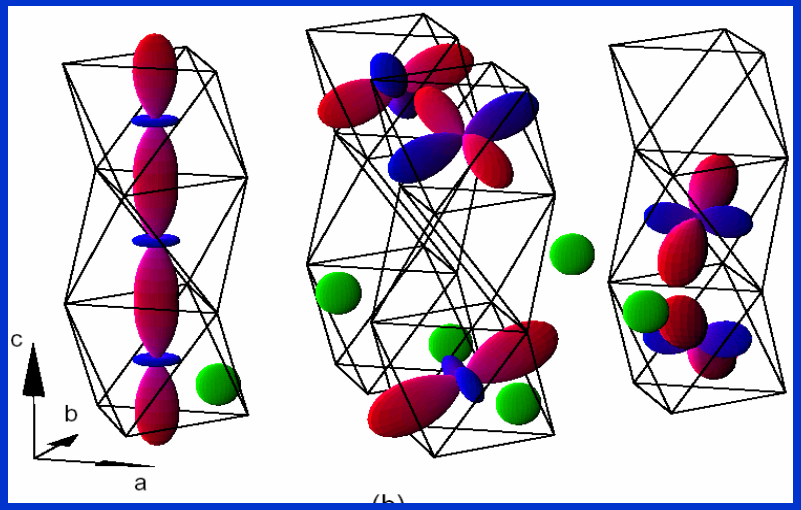


Cuprates are unconventional, d-wave superconductors!

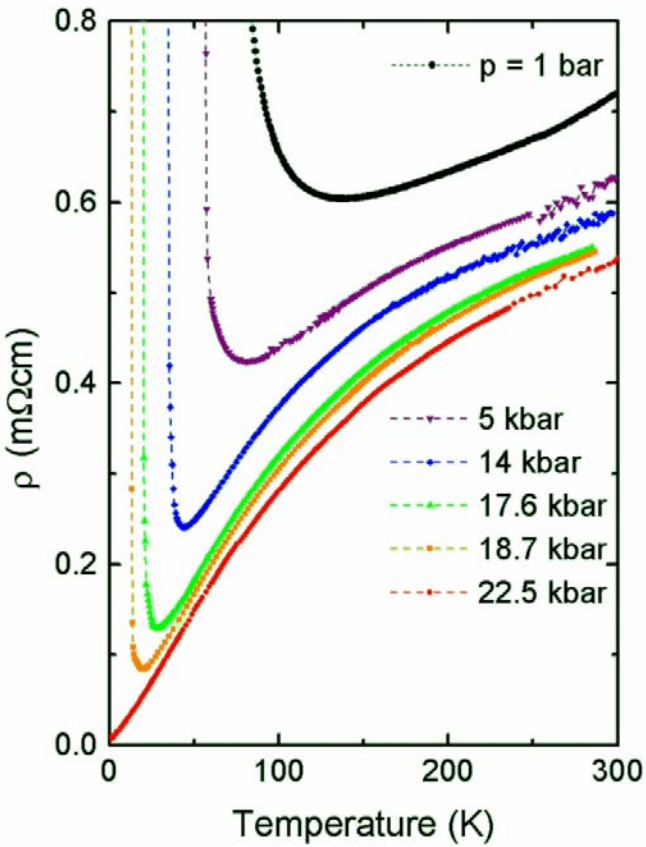
Mandrus et ak, 70, 2629 (1993)

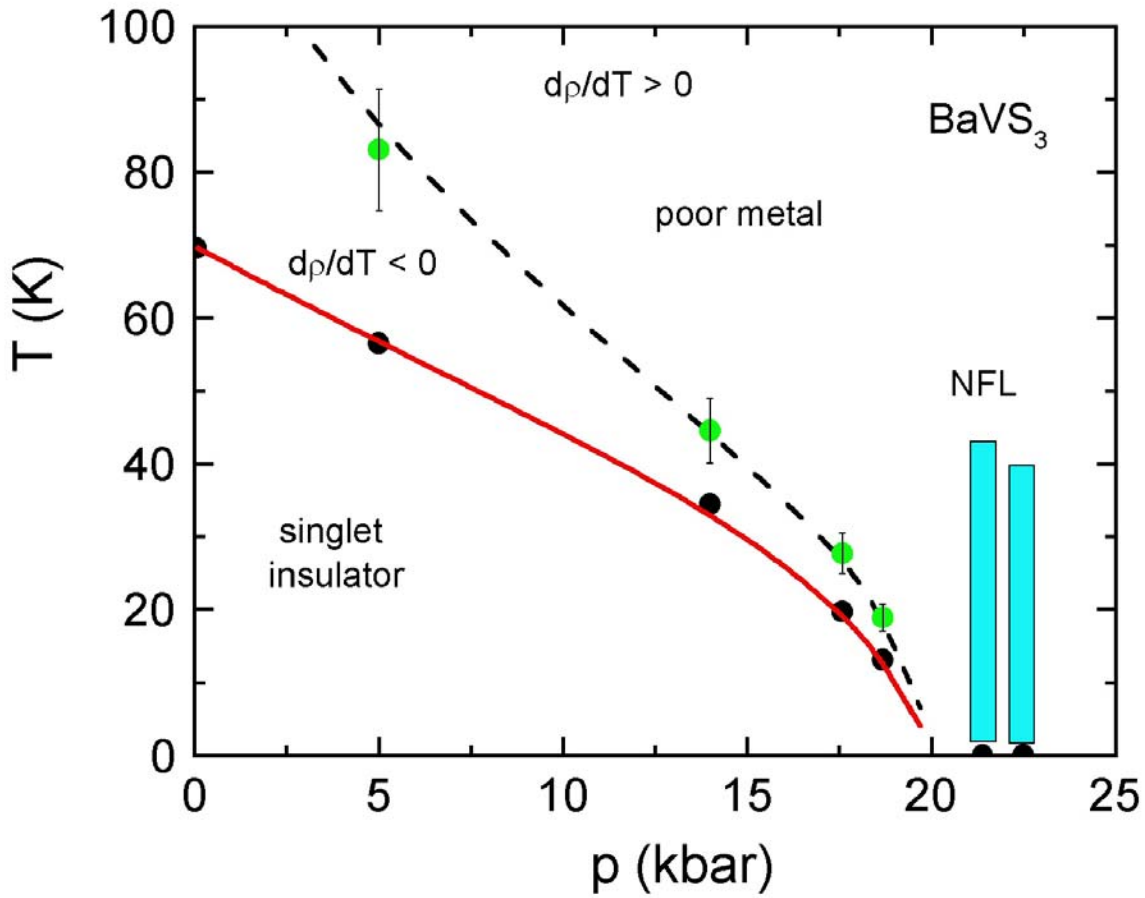
Recent work: $BaVS_3$ correlated d-electron system (on U10A)





Phase diagram



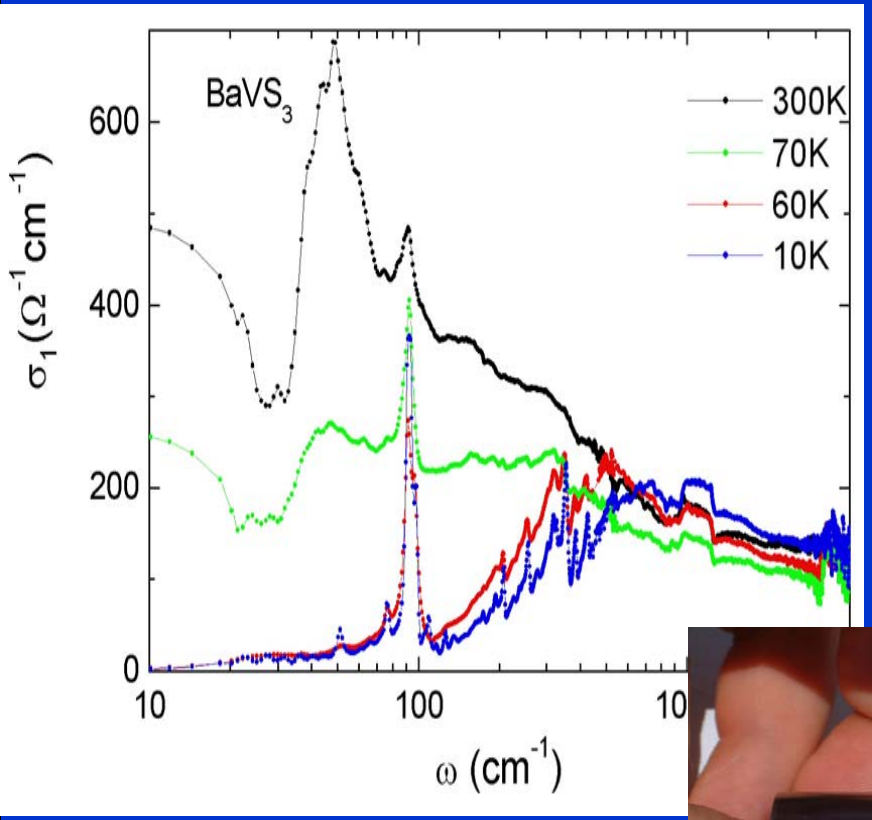


L. Forró, R. Gaál, H. Berger, P. Fazekas, K. Penc, I. Kézsmárki and G. Mihály
Phys. Rev. Lett. 85, 1938 (2000).

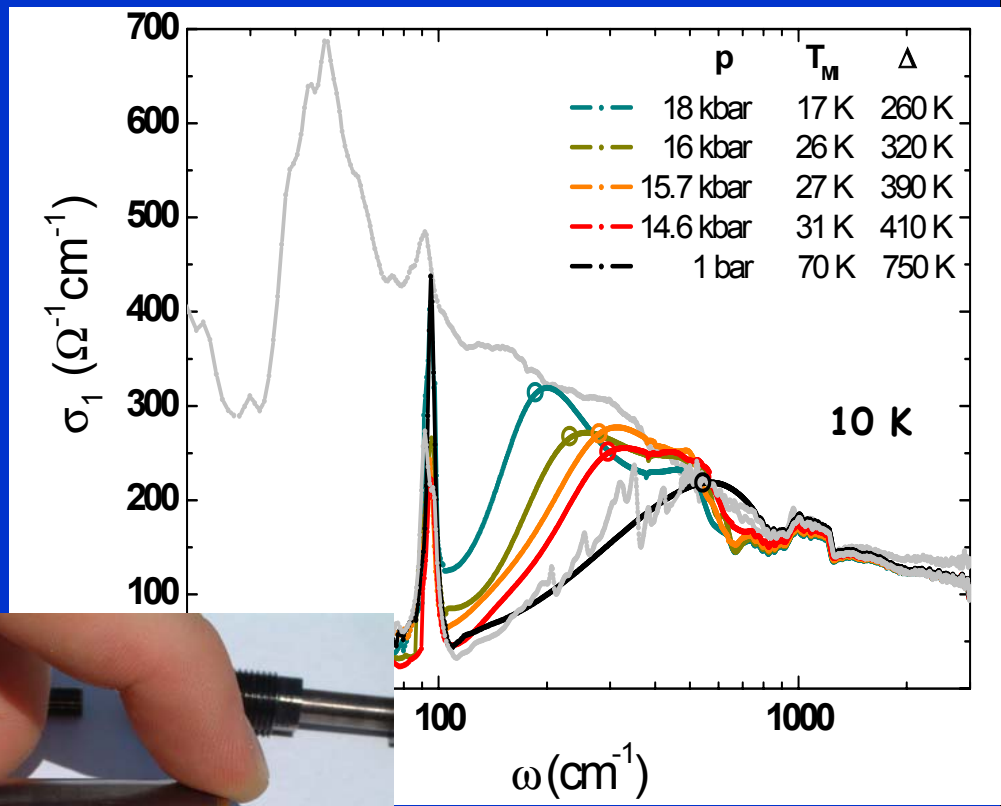
C. Homes, et al. – NSLS U10A beamline (2001-2002)

Optical conductivity in the infrared range

ambient pressure



under pressure



Δ =

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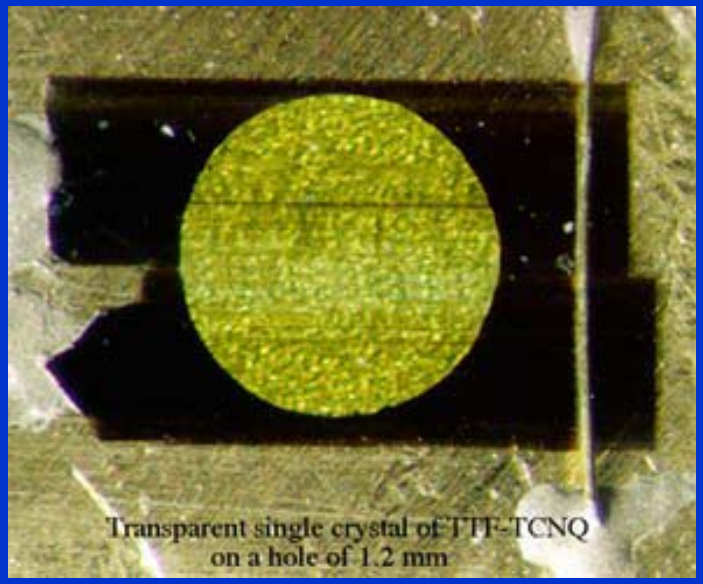
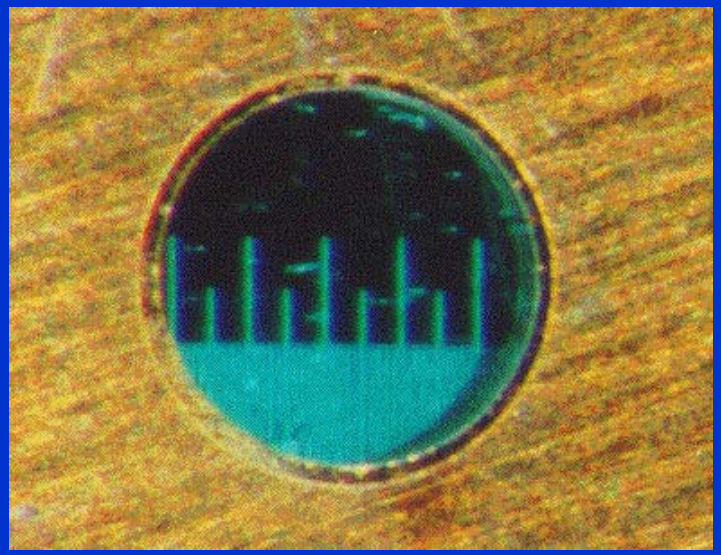
Other correlated systems studied (U4IR)

2H-$NbSe_2$: a conventional layered superconductor

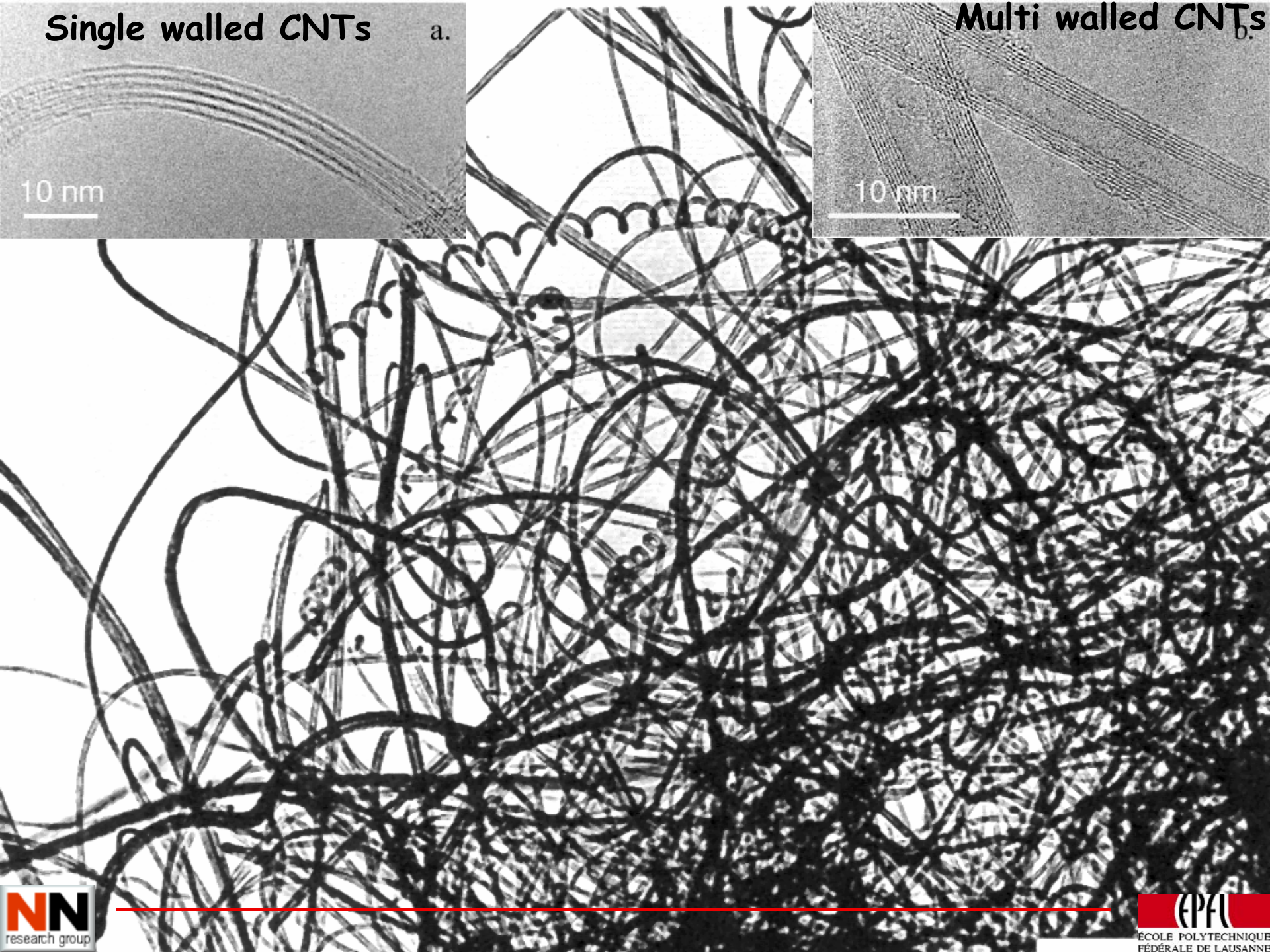
Quasi-1D organic CDW conductors



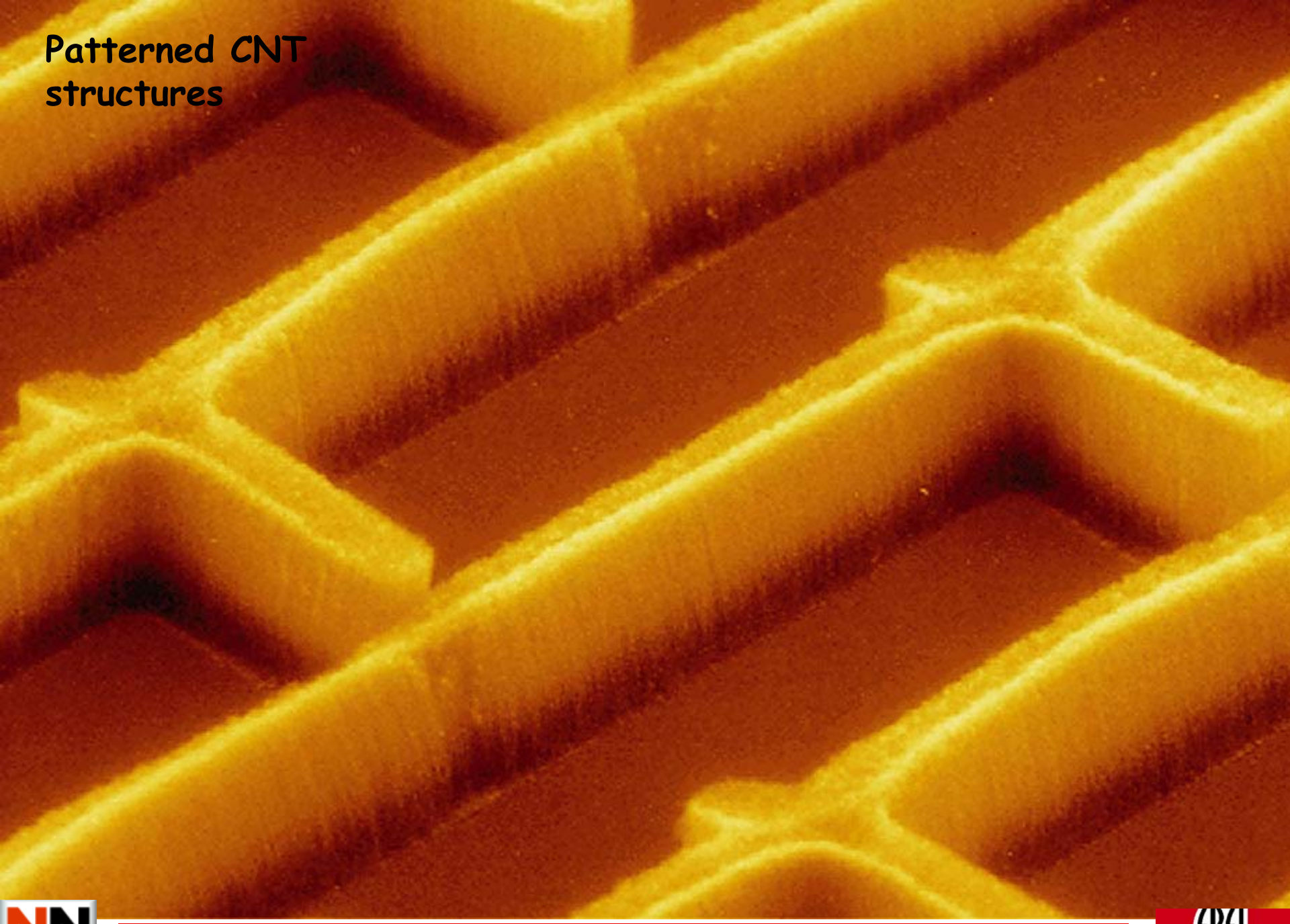


Blue bronze
Peierls transition at 180 K

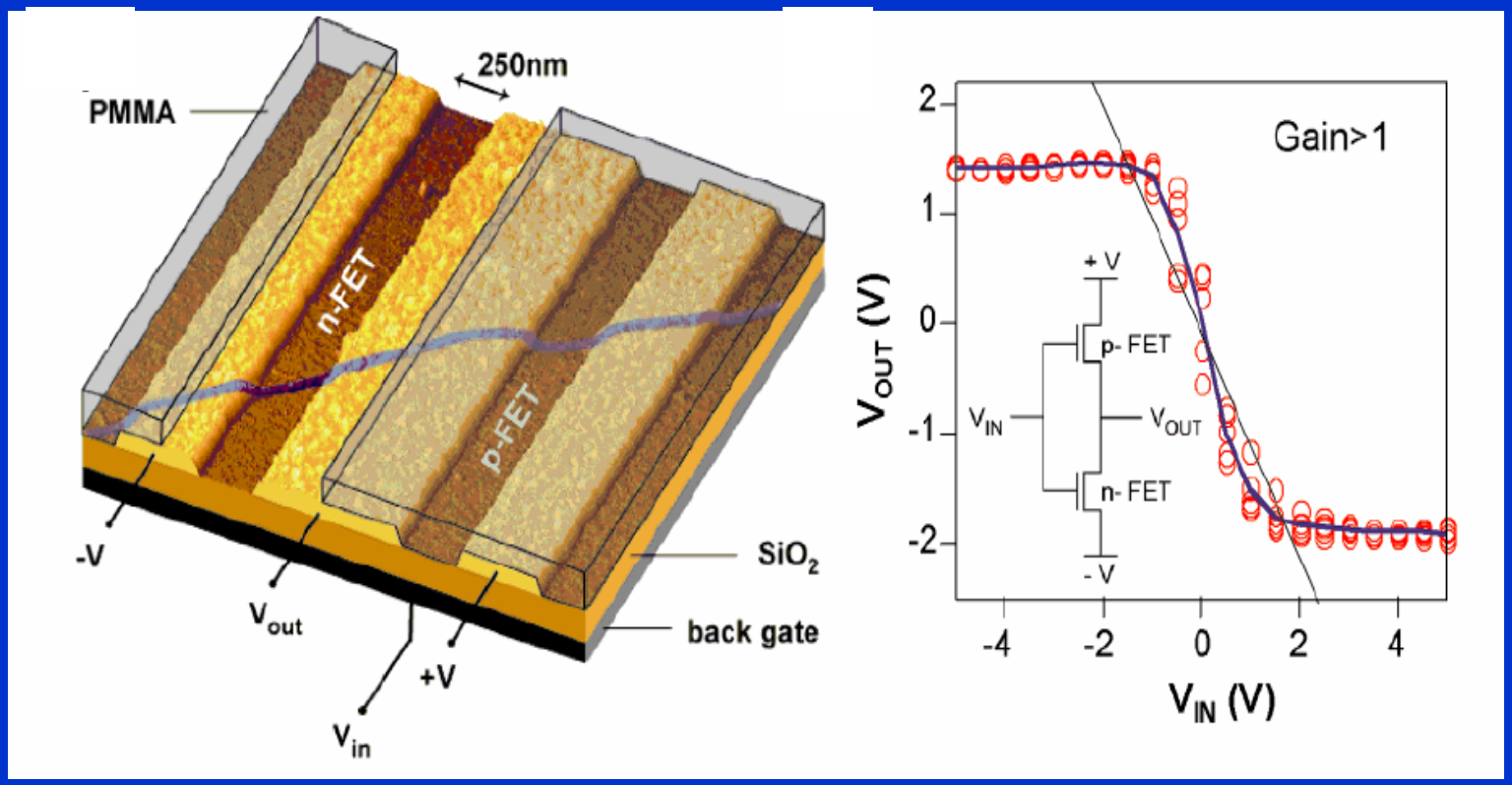
Nanostructures – carbon nanotubes


Single walled CNTs
a.
10 nm
Multi walled CNTs
b.
10 nm

Patterned CNT structures

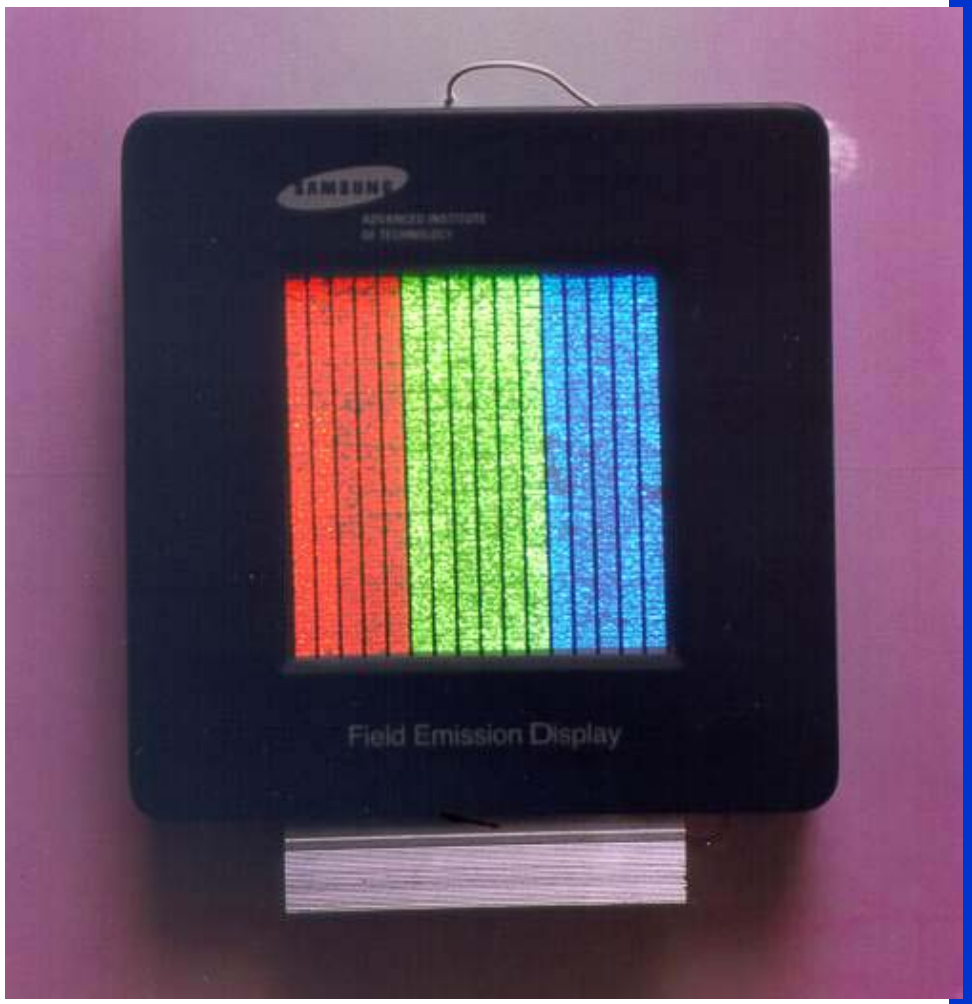


Logic circuit – IBM (Derycke et al, Nanoletters, New York Times (2001)



Flat panel screen

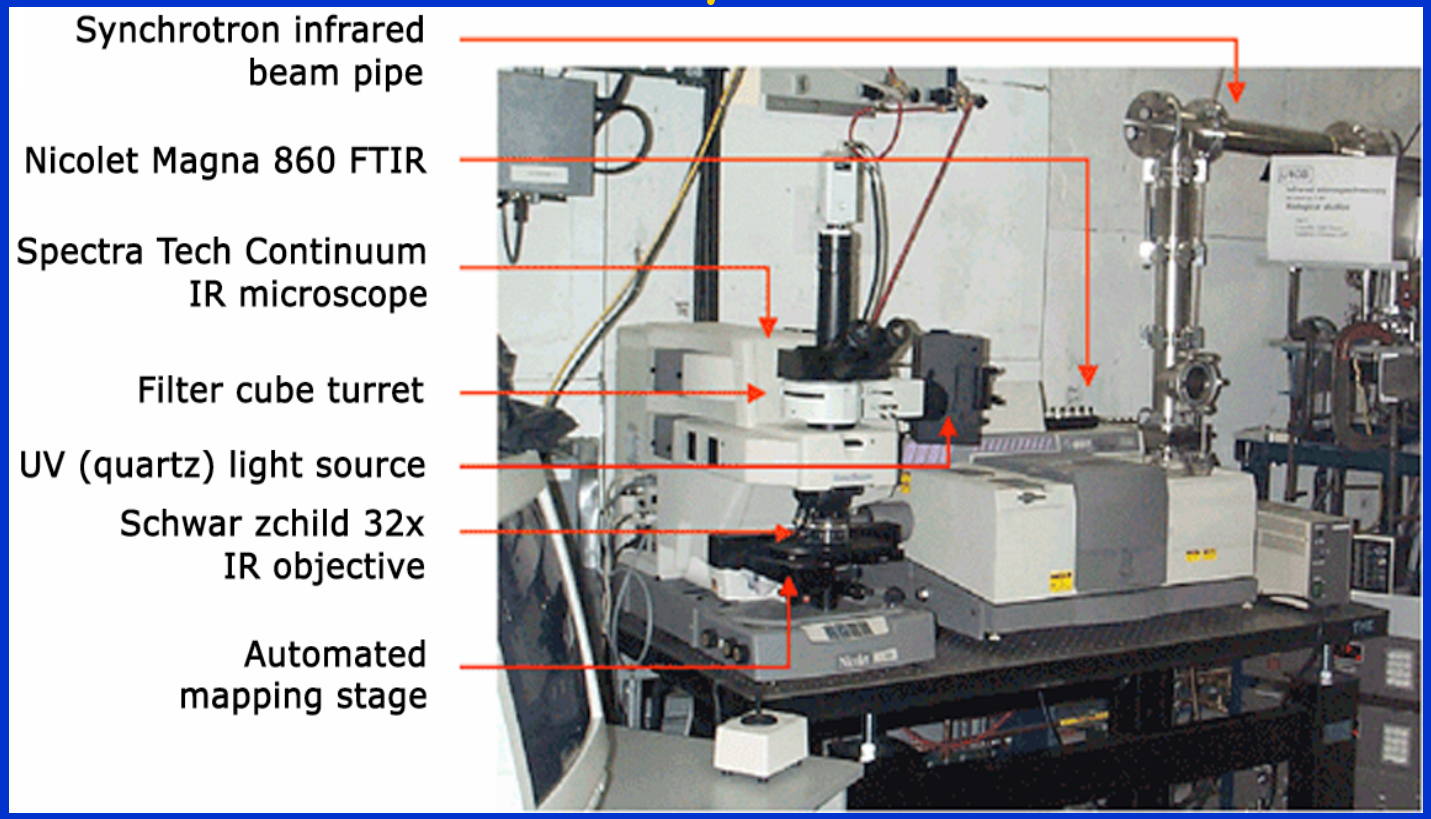
- Samsung:
  - 4.5" color screen



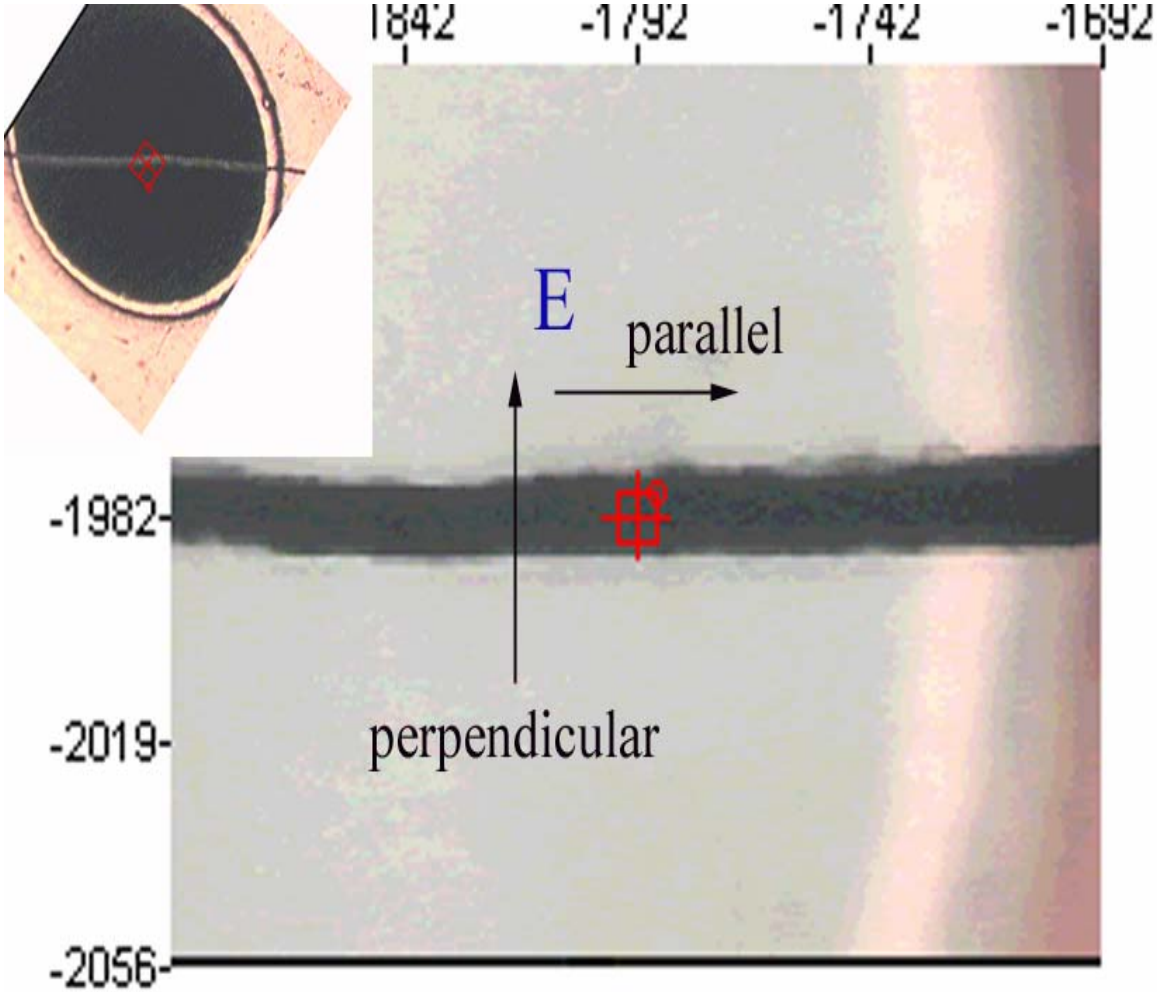
Choi et al., APL 75, 3129 (1999)

IR microspectroscopy of nanotubes (on U10B)

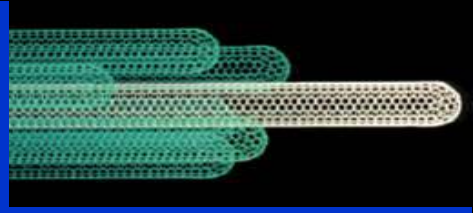
- Gives local, chemically sensitive information

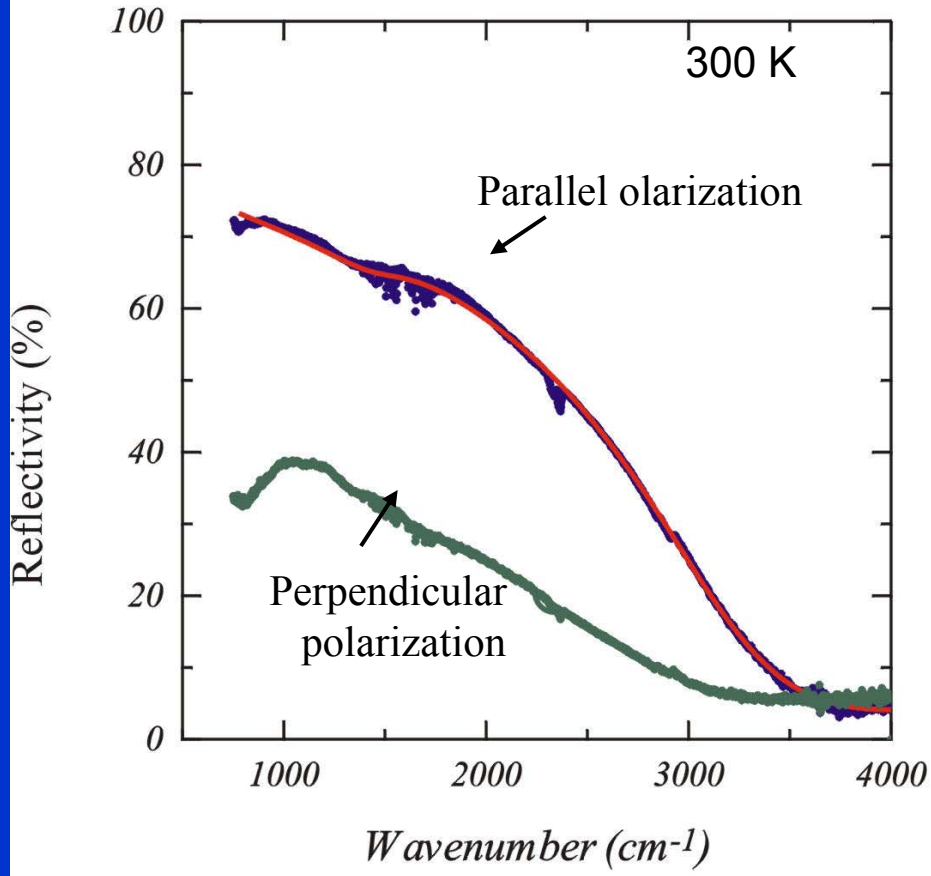


Example: optical conductivity of aligned ropes of carbon nanotubes

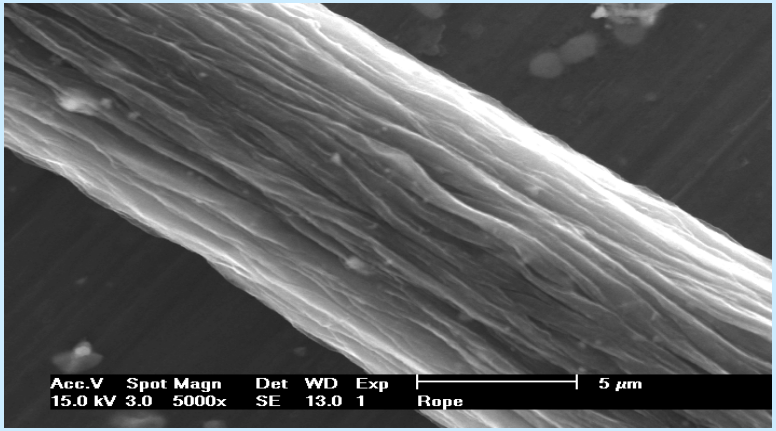


Experiment on SWNT ropes





- Good metallic behavior for $E_{||}$

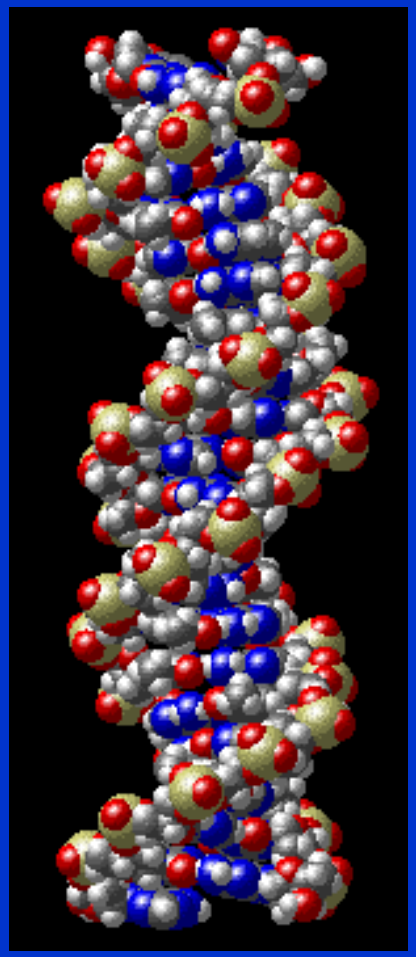


- Large anisotropy

R. Gaál et al., in preparation

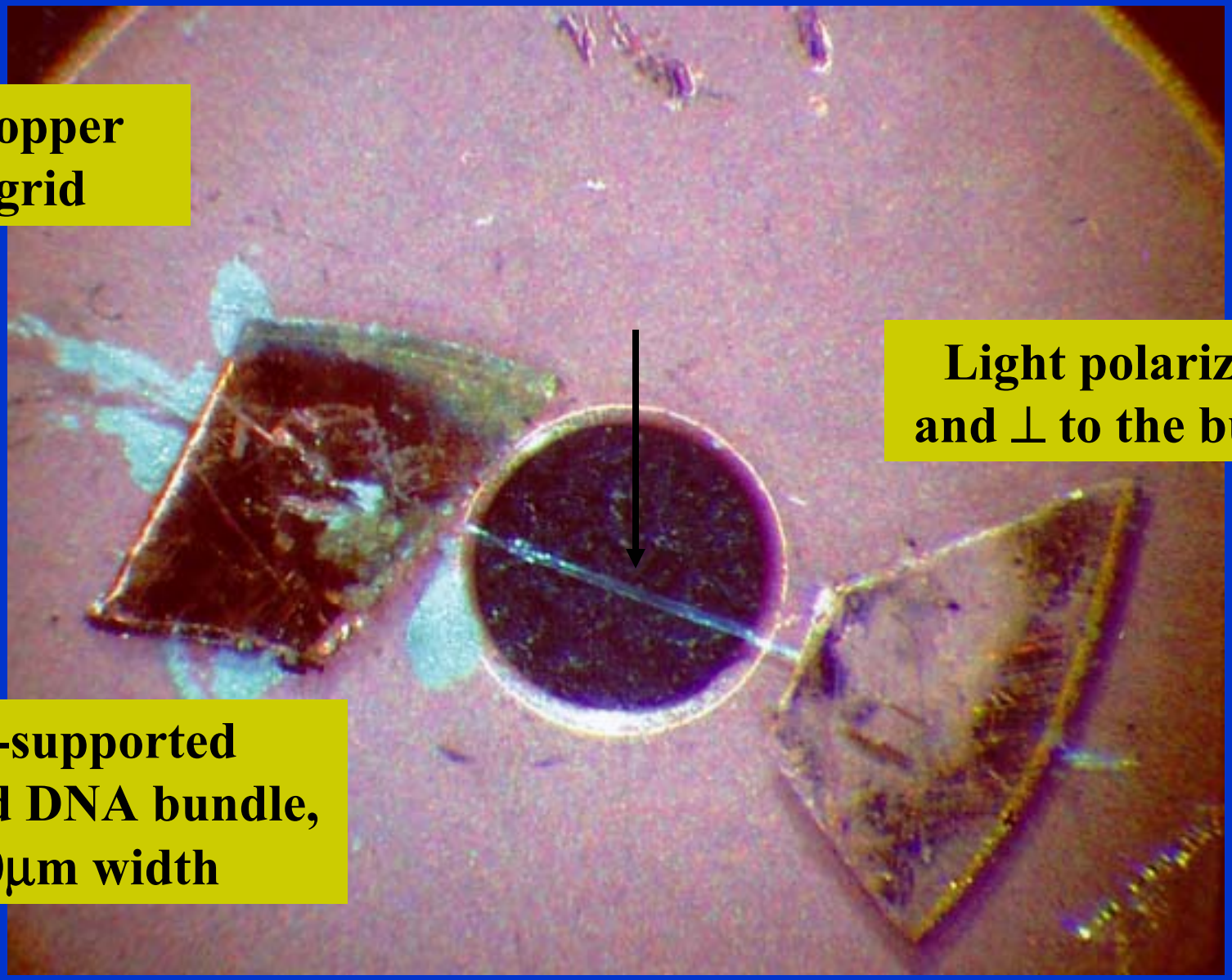
Biomatter

Charge Transport in DNA

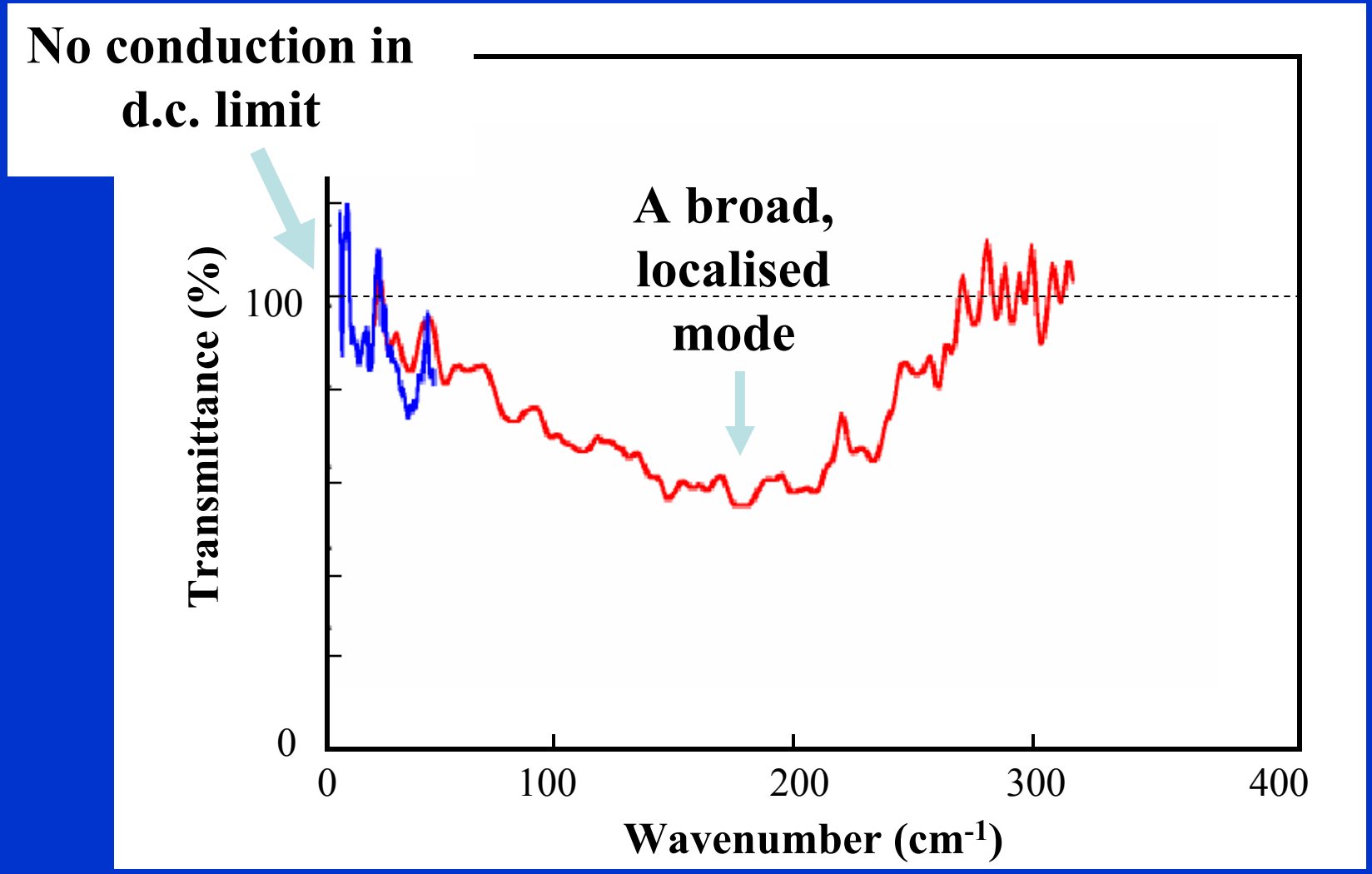


- Insulates like diamond (Broun et al., Nature'98)
- Semiconducts (Porath et al., Nature'2000); Tran et al., Phys.Rev.Lett.'2000).
- Conducts like a metal (Fink et al., Nature'99).
- Superconducts (proximity effect) (Kasumov et al. Science'2001).

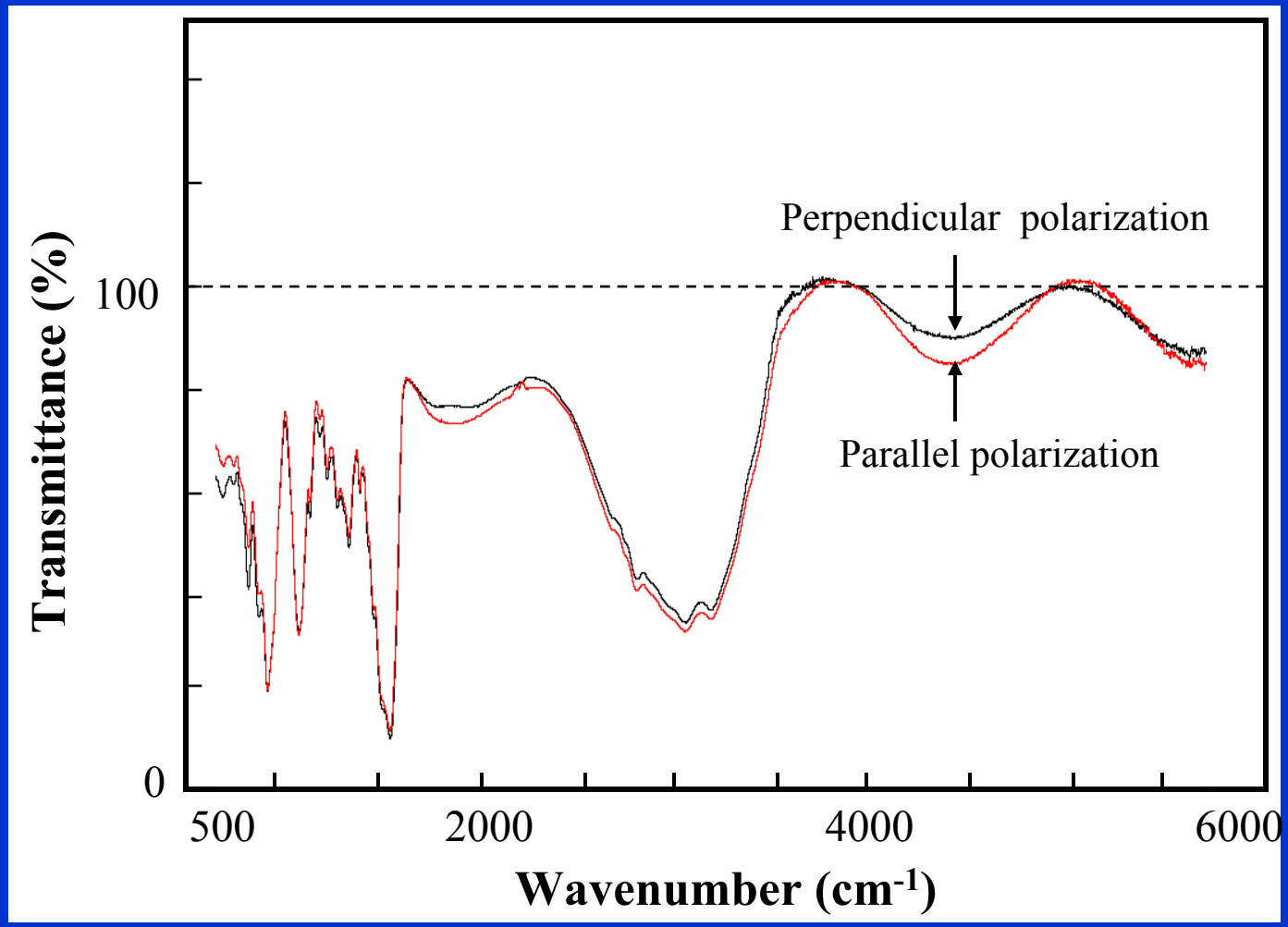
Aligned bundle of λ-DNA



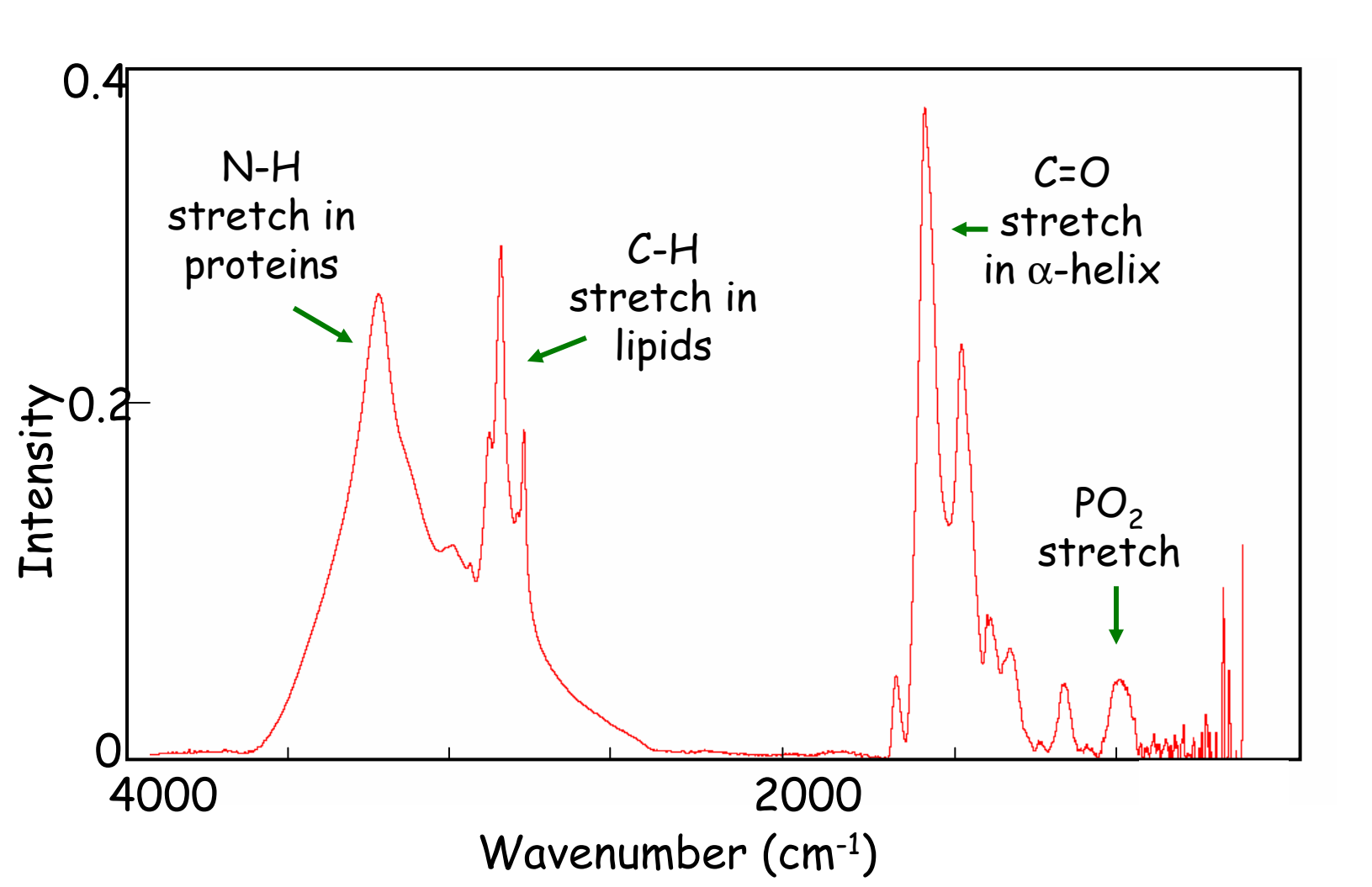
the low energy part… (on U12IR)



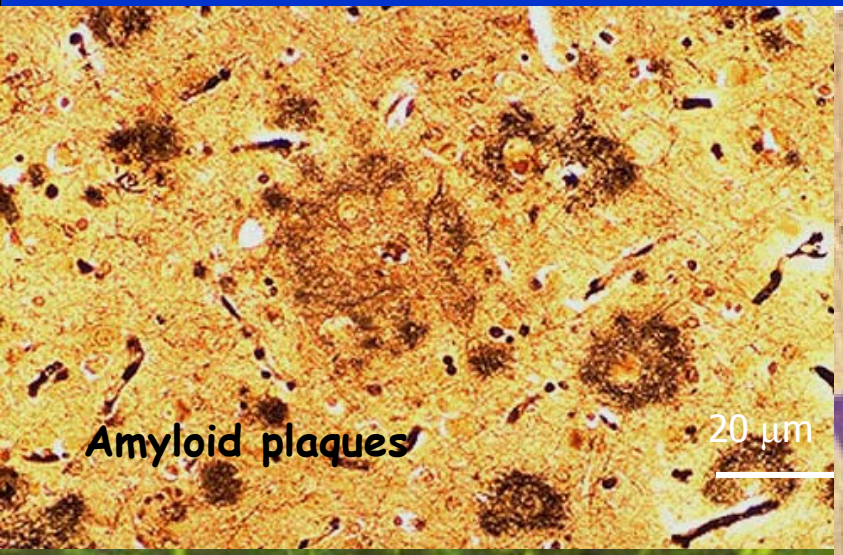
Results… (on U10B)

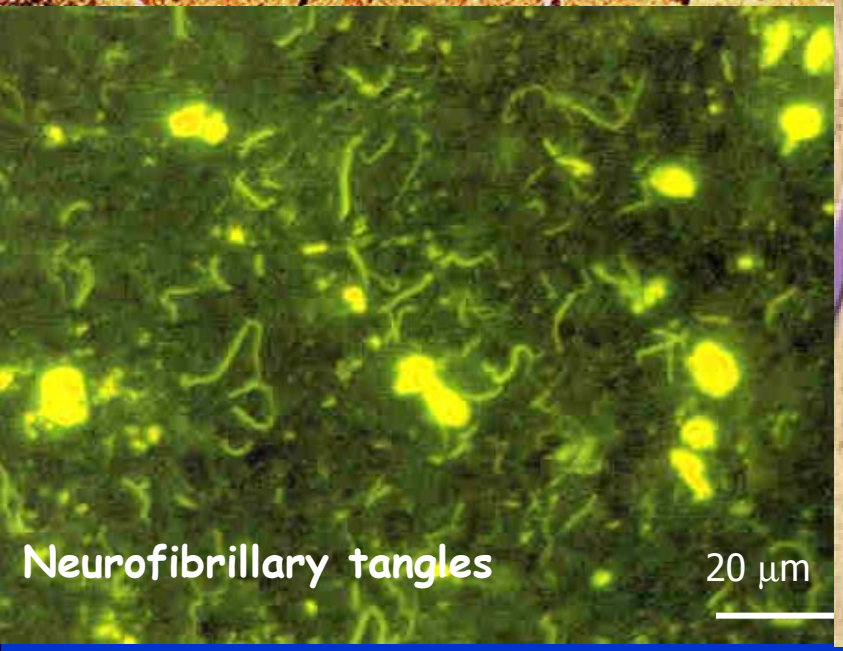


Phonon structure of a protein: their variation can be used for diagnostic purposes

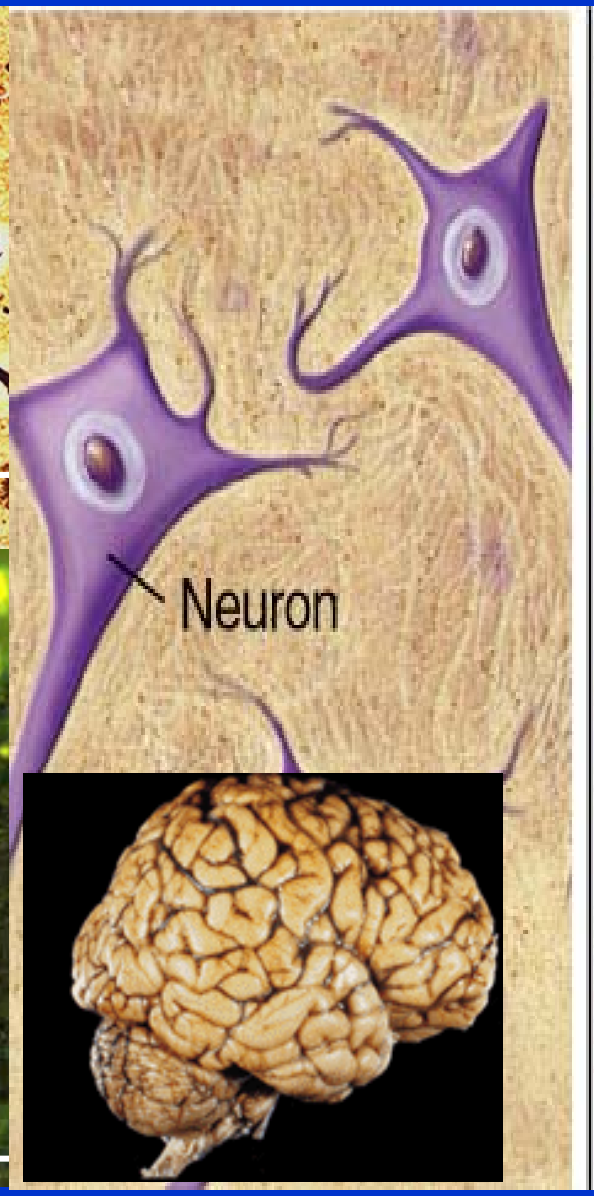


Alzheimer's disease

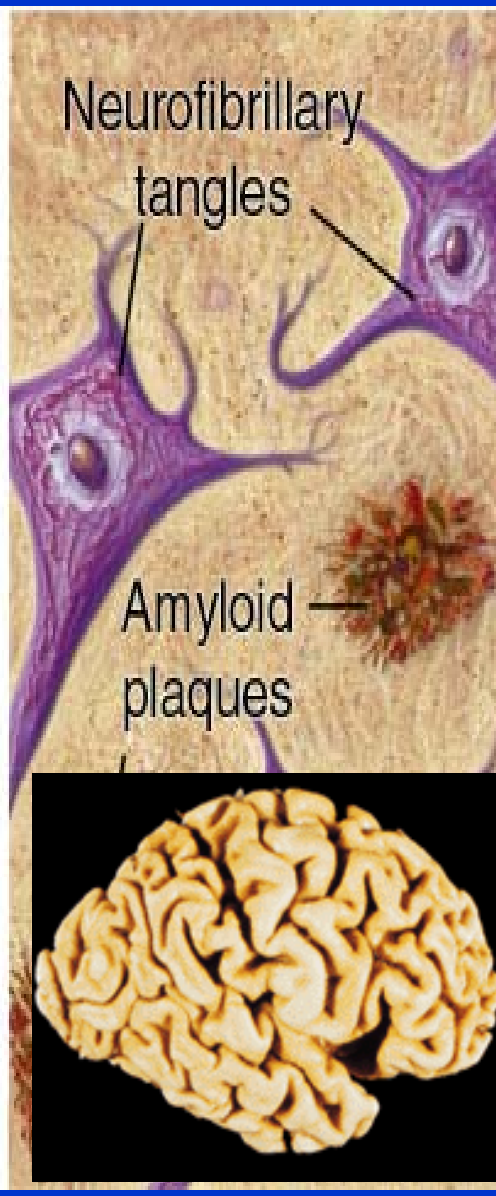




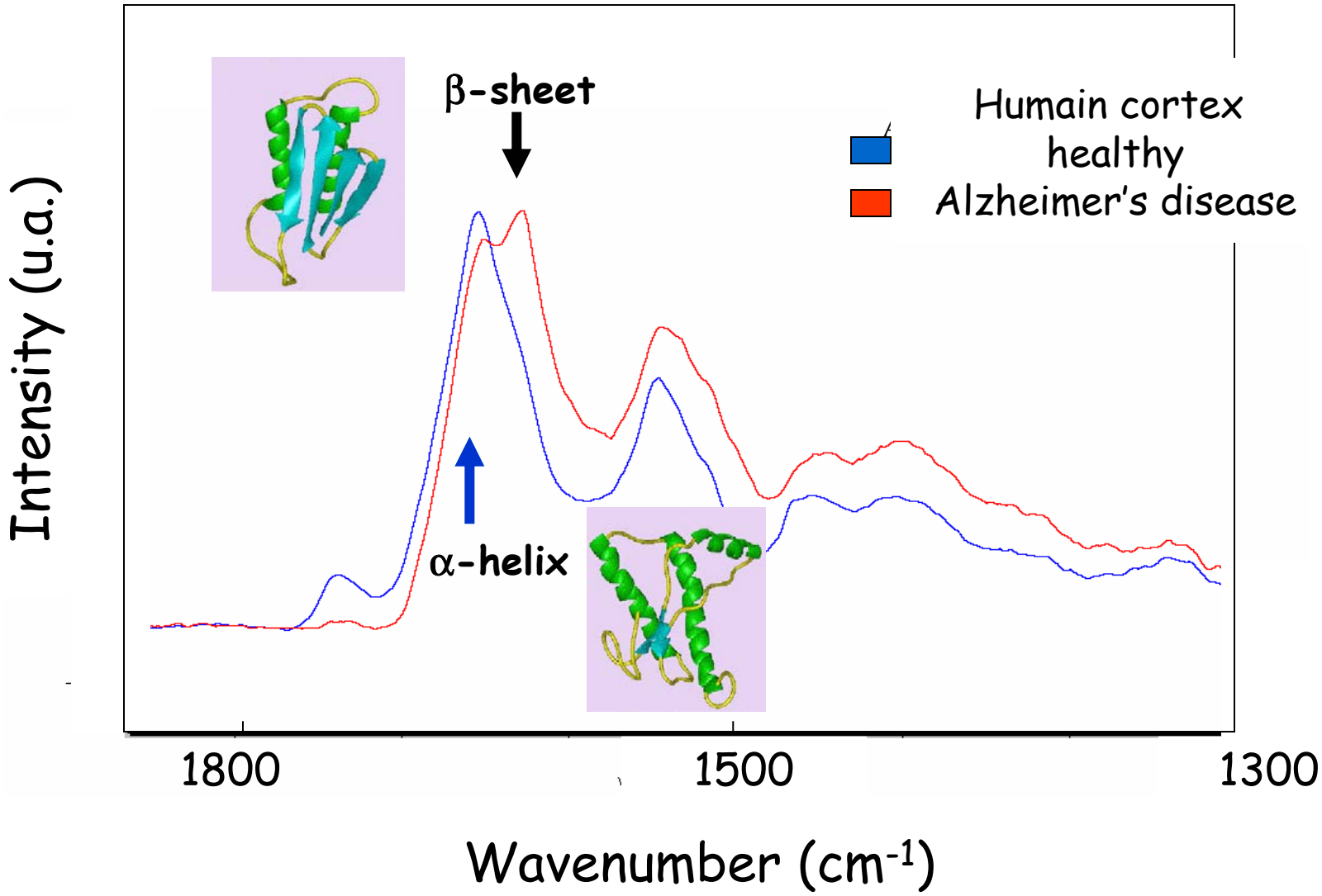
Normal



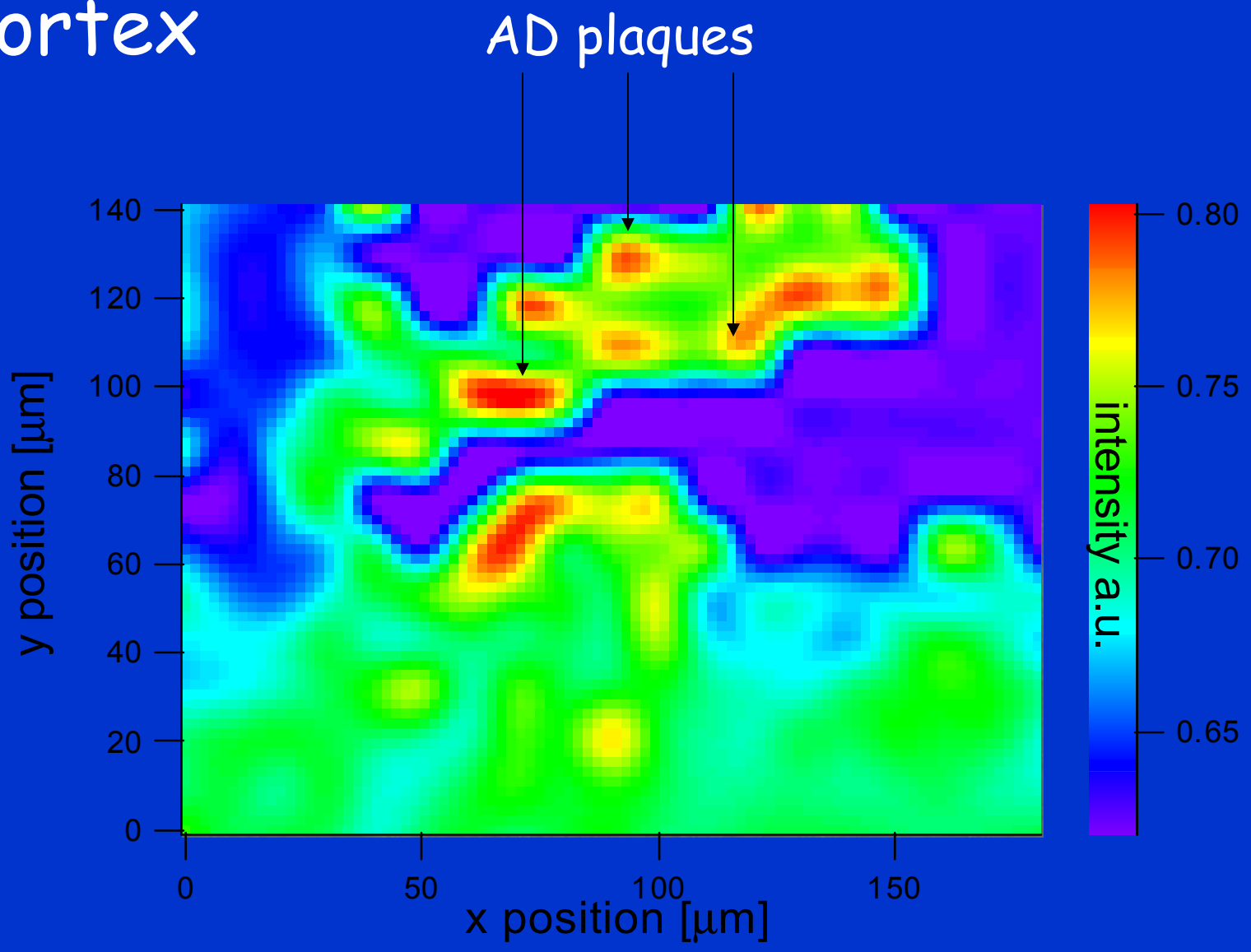
Alzheimer's



Conformation change of a protein

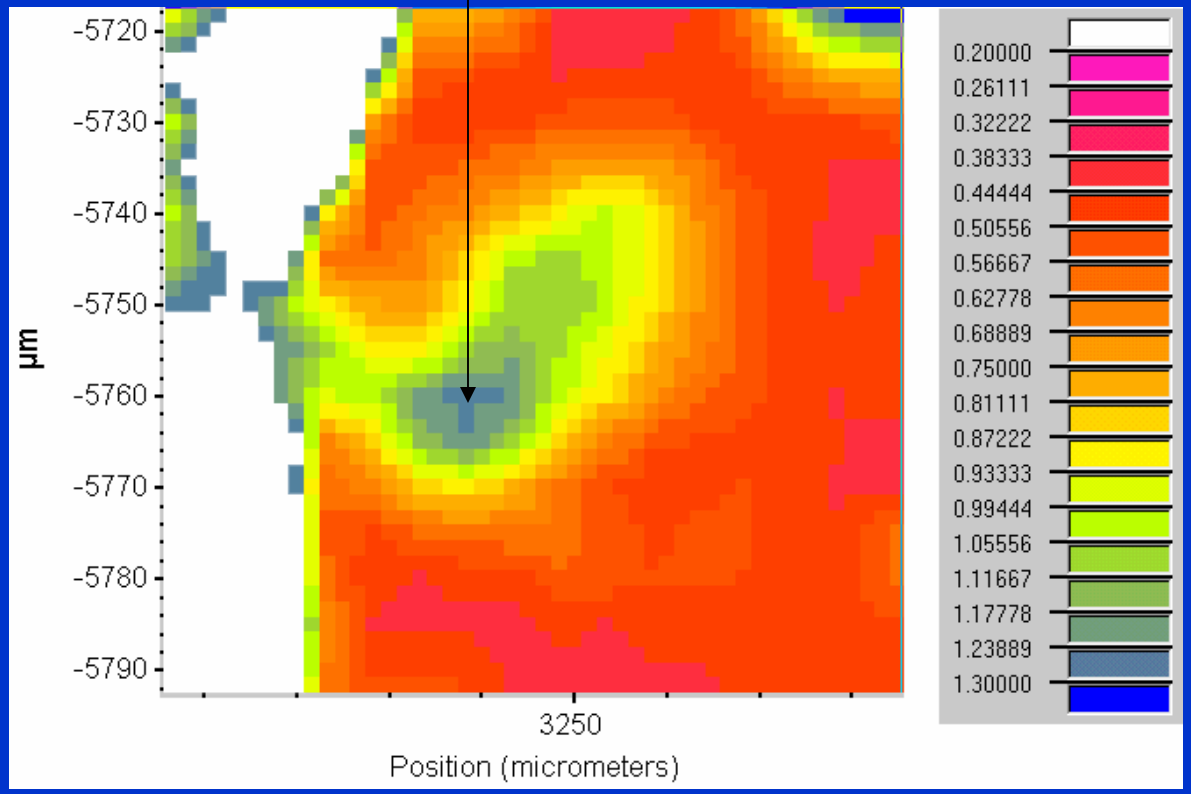


Cortex


AD plaques
140
120
100
80
60
40
20
0
y position [µm]
0
50
100
150
x position [µm]
0.80
0.75
0.70
0.65
intensity a.u.

Pancreas

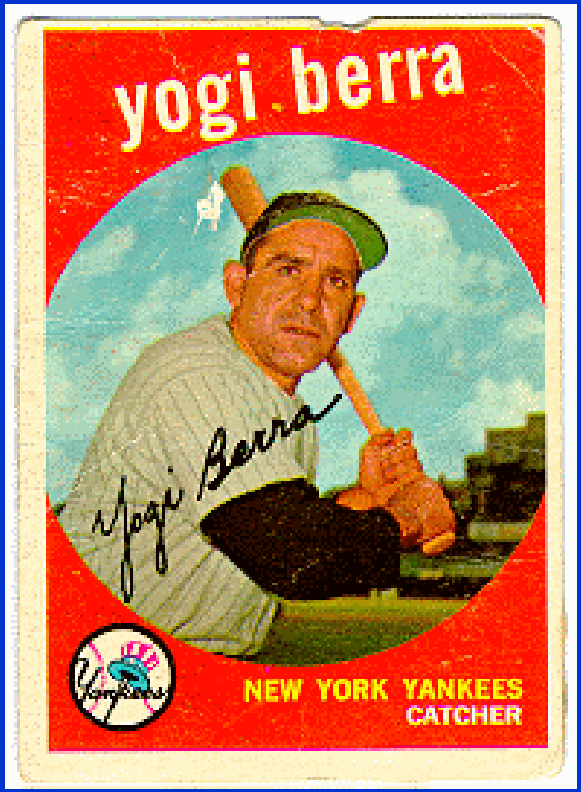
β-sheets plaques



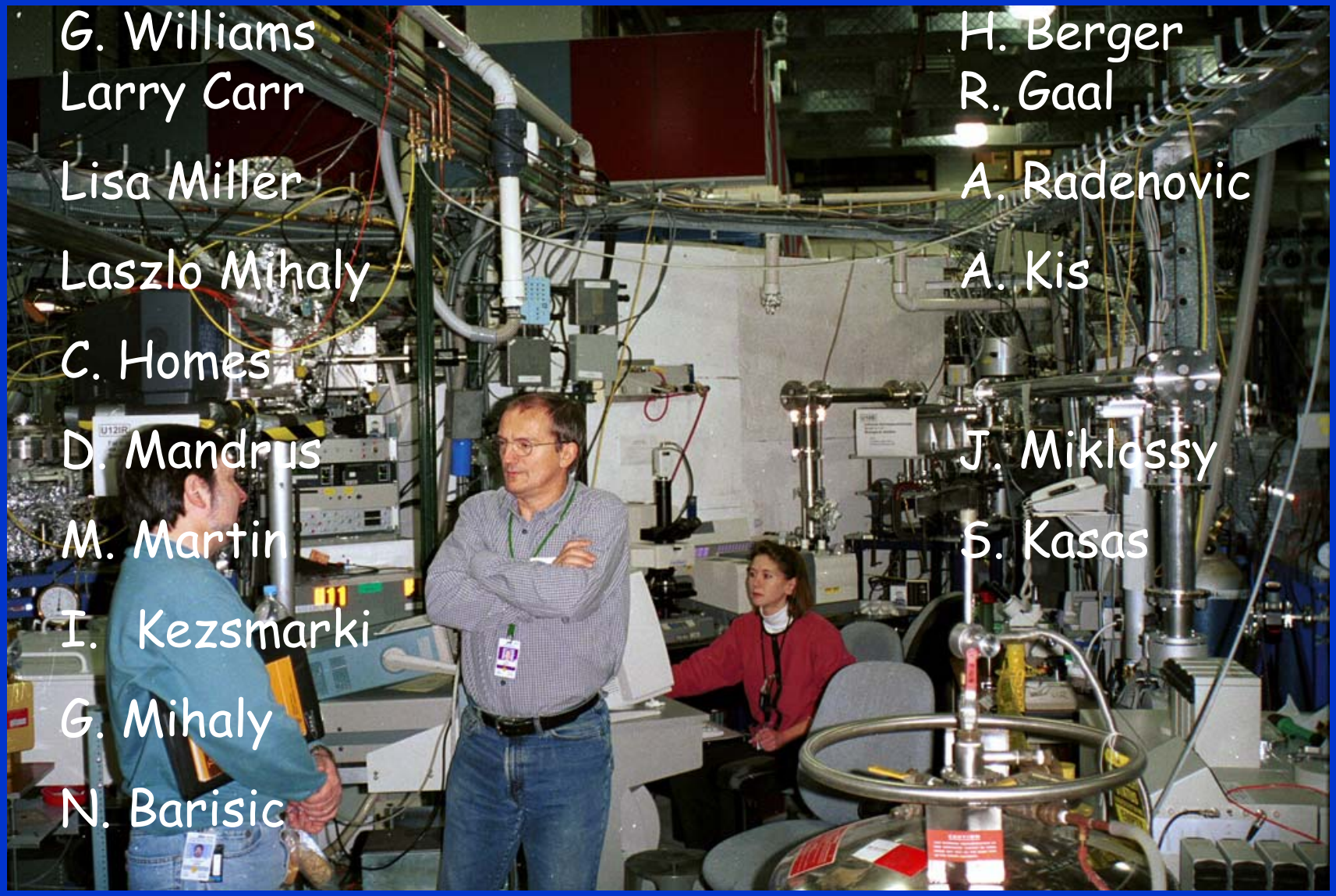
Conclusion

"You can observe a lot,

just by watching…"



Acknowledgments…



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Thank you for your attention