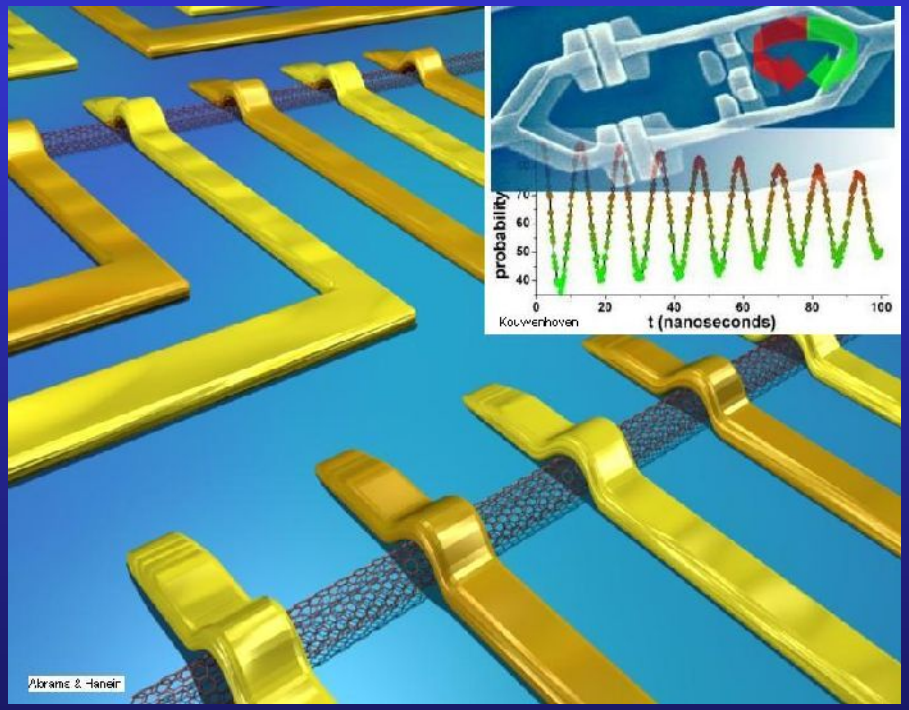
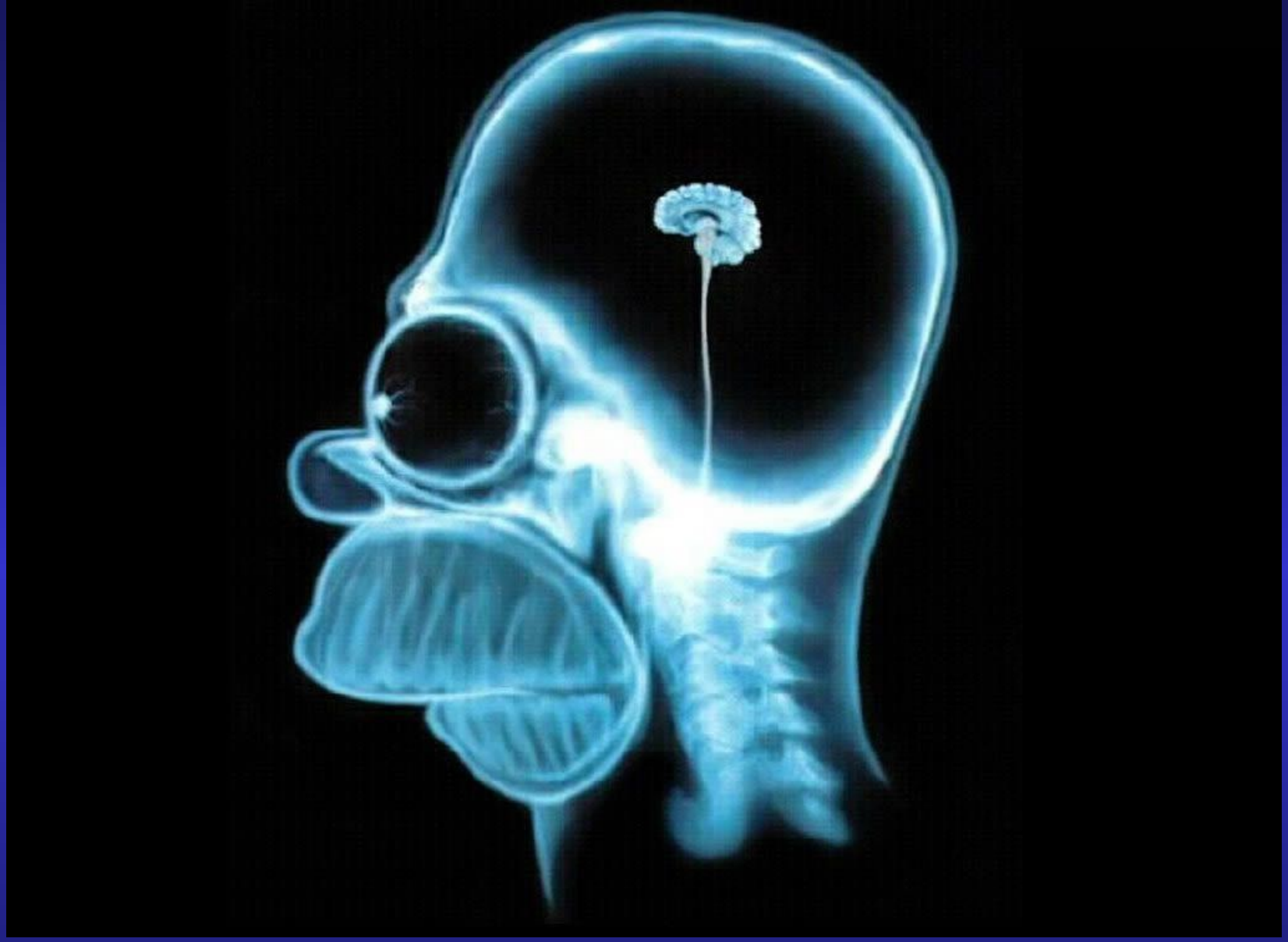
Why does Homer need a quantum computer?



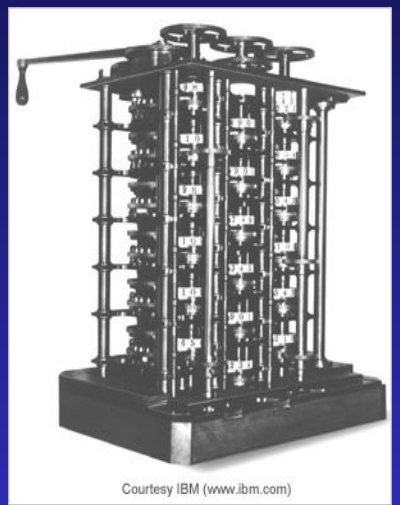
McGill
Homer



Can we help Homer?

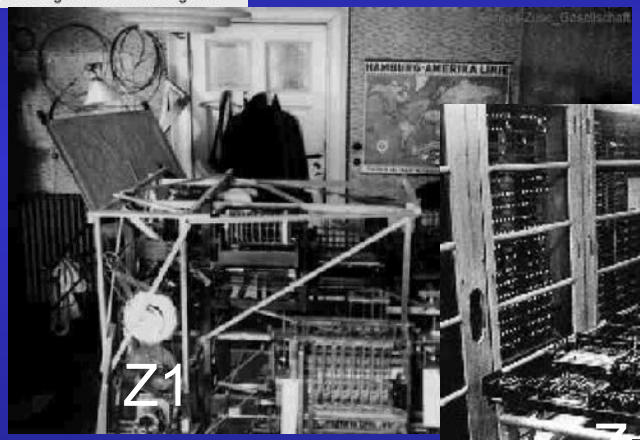
Prehistory

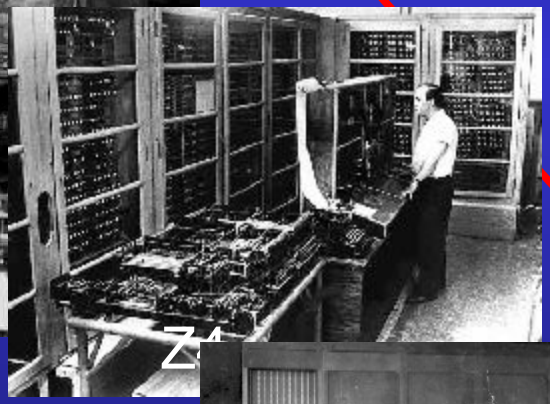
19th century: (Babbage)

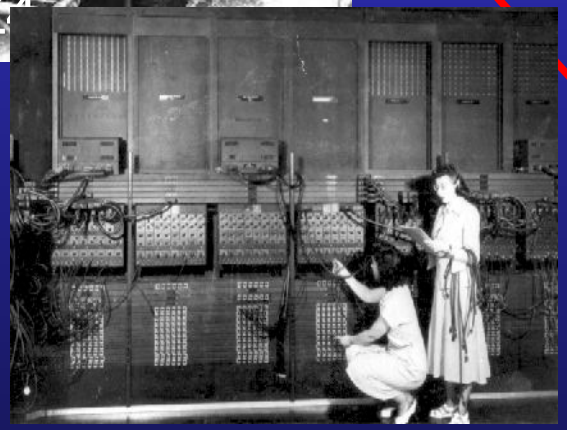


Part of one of Babbage's Difference Engines

2nd World war (Zuse)







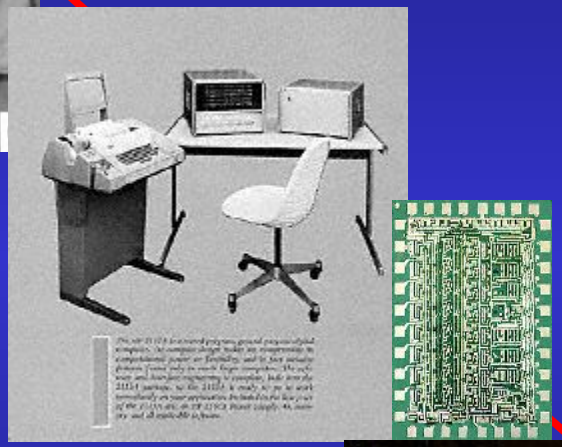
ENIAC '44

History

1947: first transistor

1958: first IC (Kilby)

1966: first Office computer (HP-2115)



1977: first PC (Apple II)

History

1990: digital cell phone

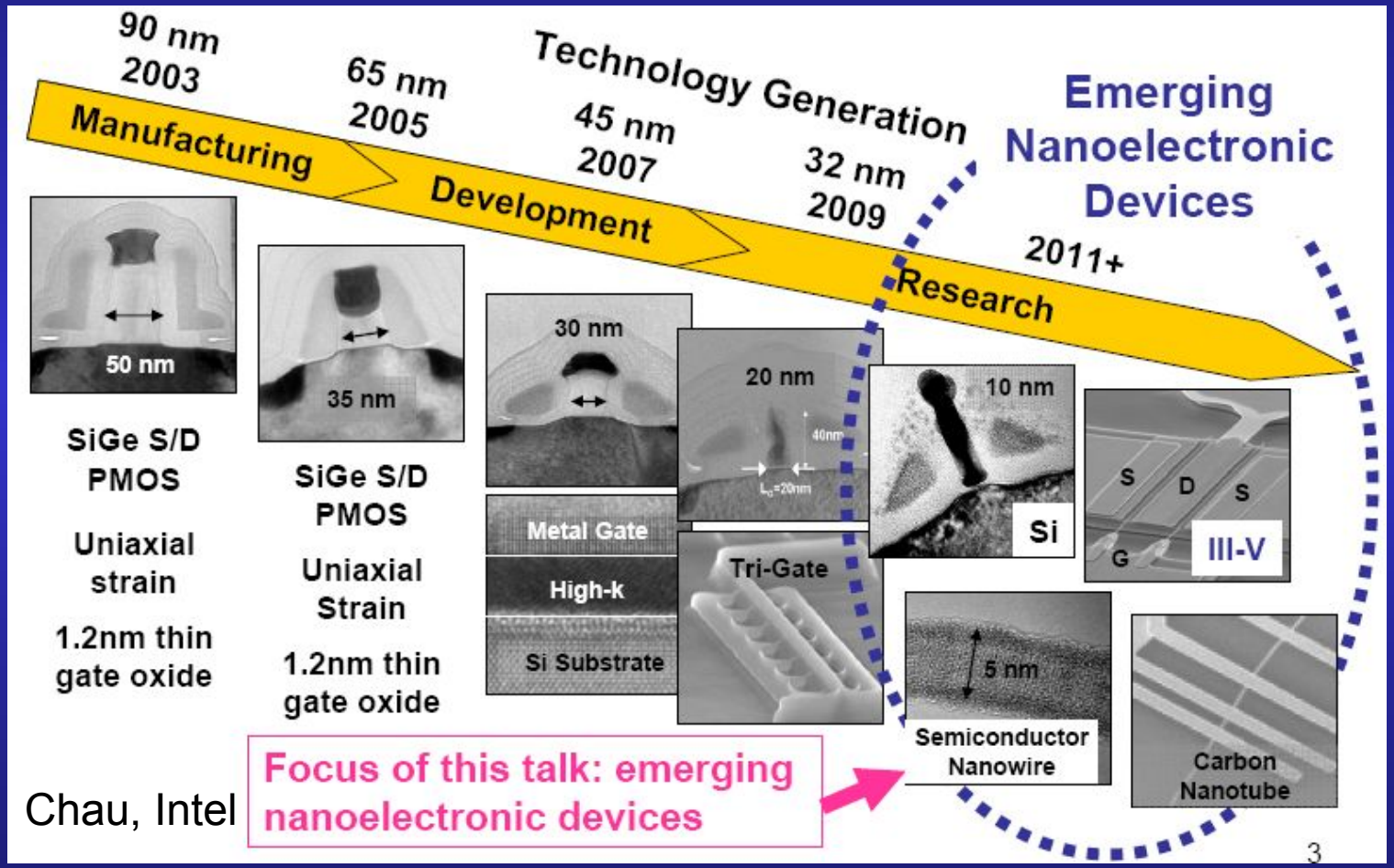
1991: WWW

1997: blackberry

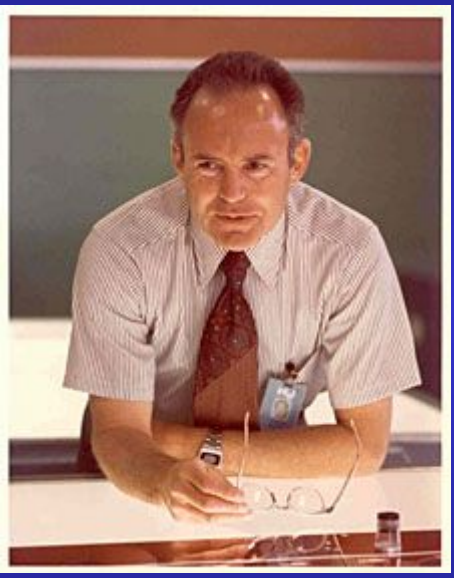
2001: Ipod

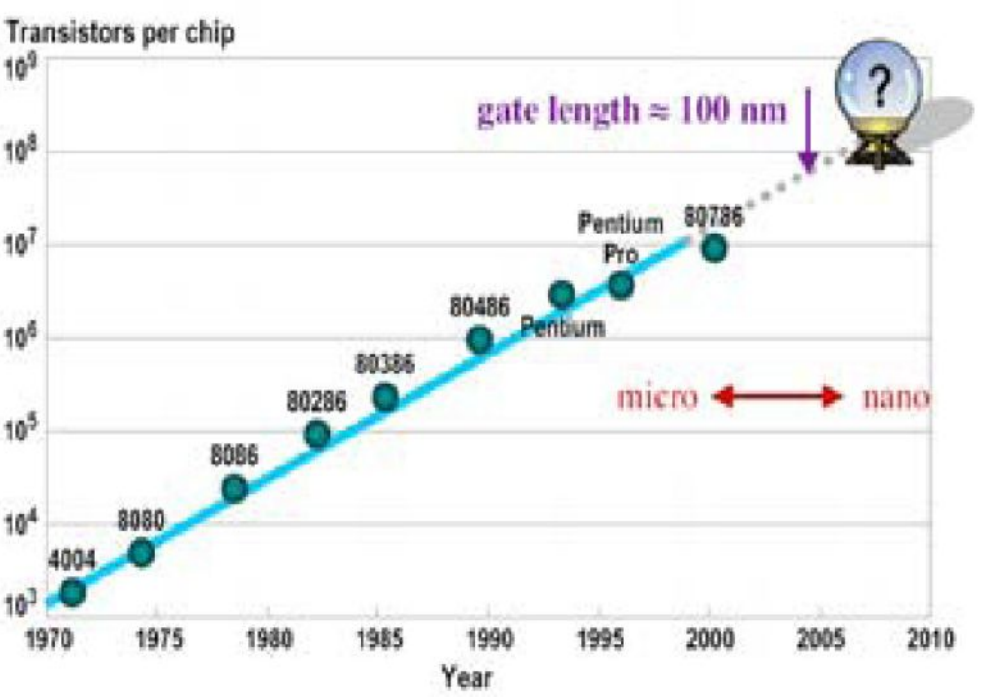
2008: ?

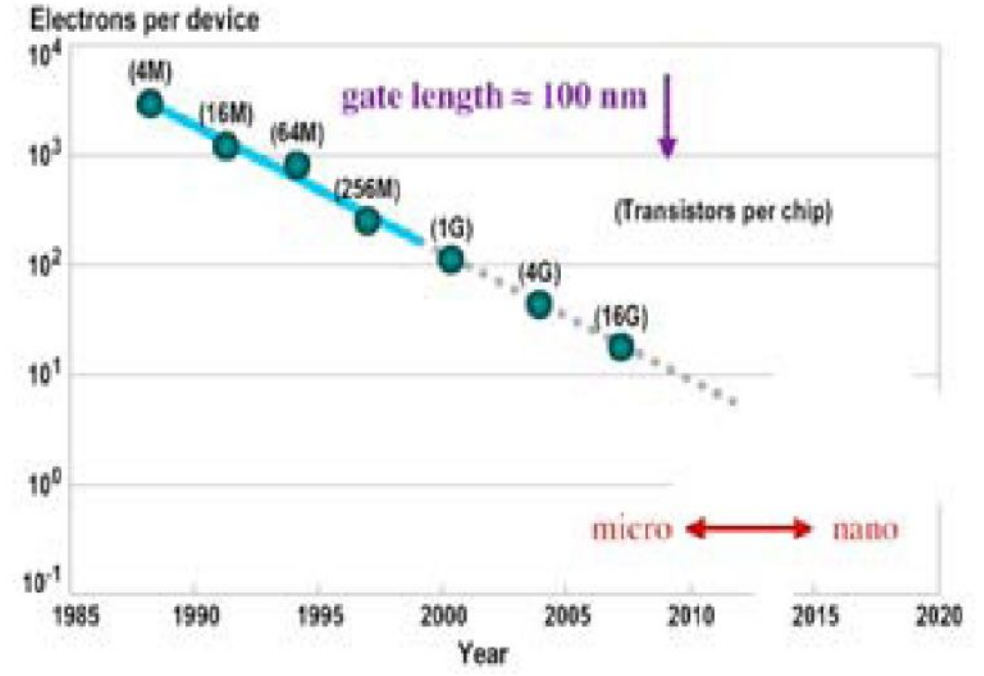
Present and Future:



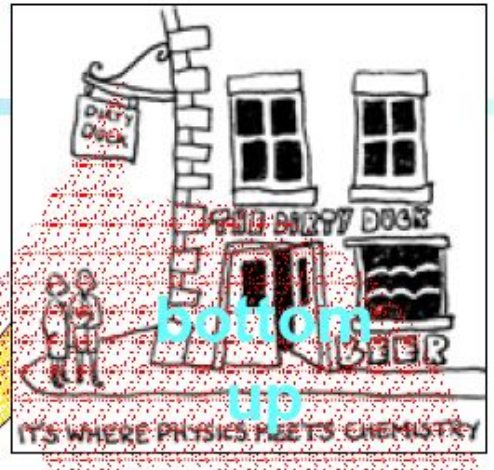
Moore's law

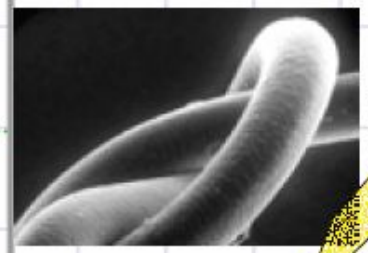


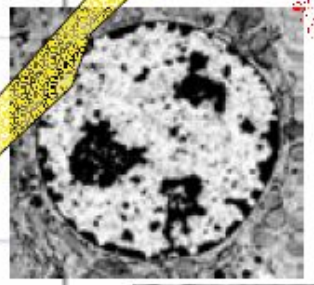

Transistors per chip
gate length ≈ 100 nm
Pentium Pro
80786
80486
Pentium
80386
80286
8086
8080
4004
micro
nano
Year

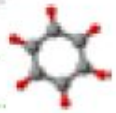

Electrons per device
(4M)
(16M)
(64M)
(256M)
(1G)
(4G)
(16G)
gate length ≈ 100 nm
(Transistors per chip)
micro
nano
Year

IC roadmap „downscaling“







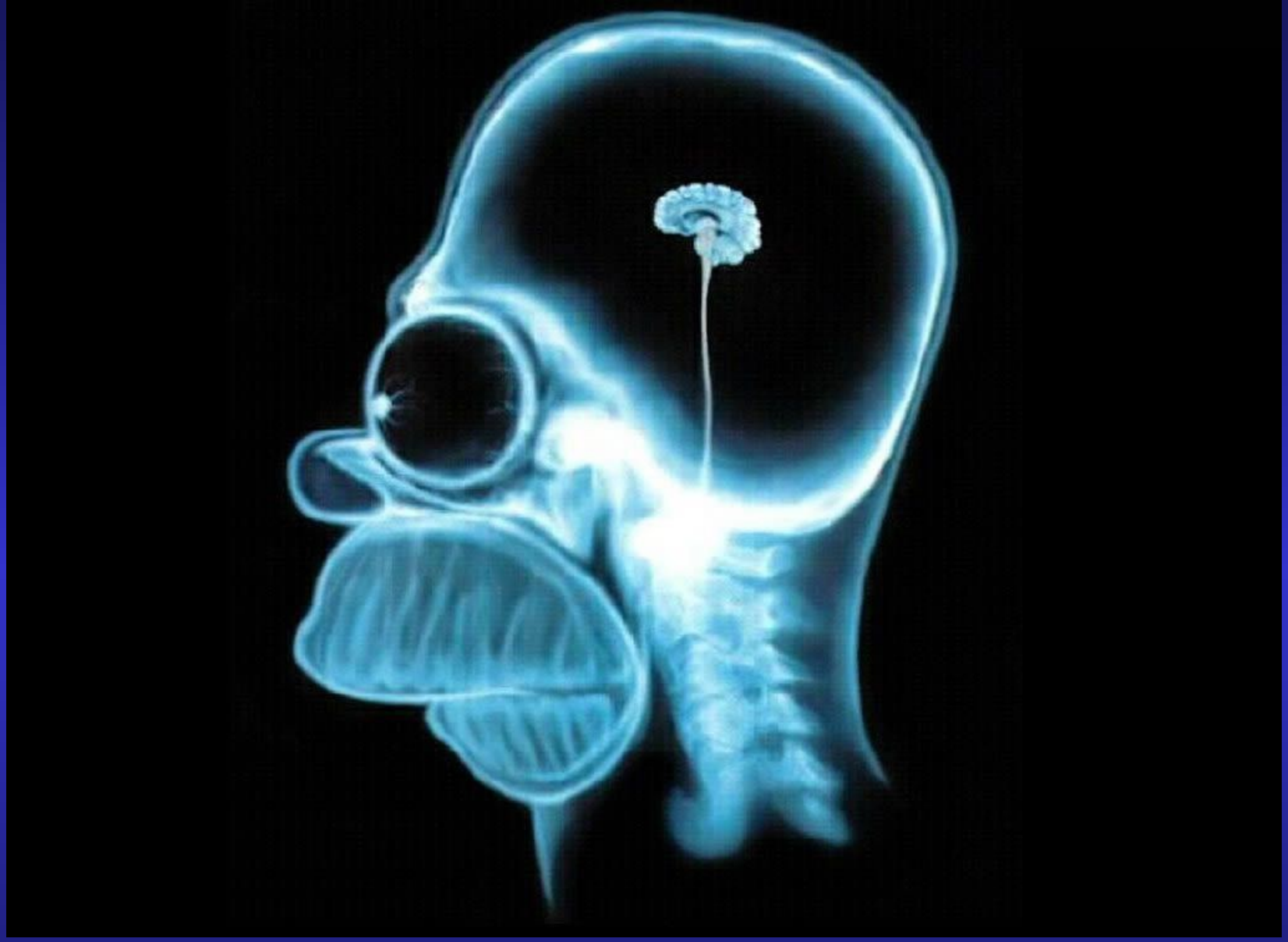


Basel group

NANO

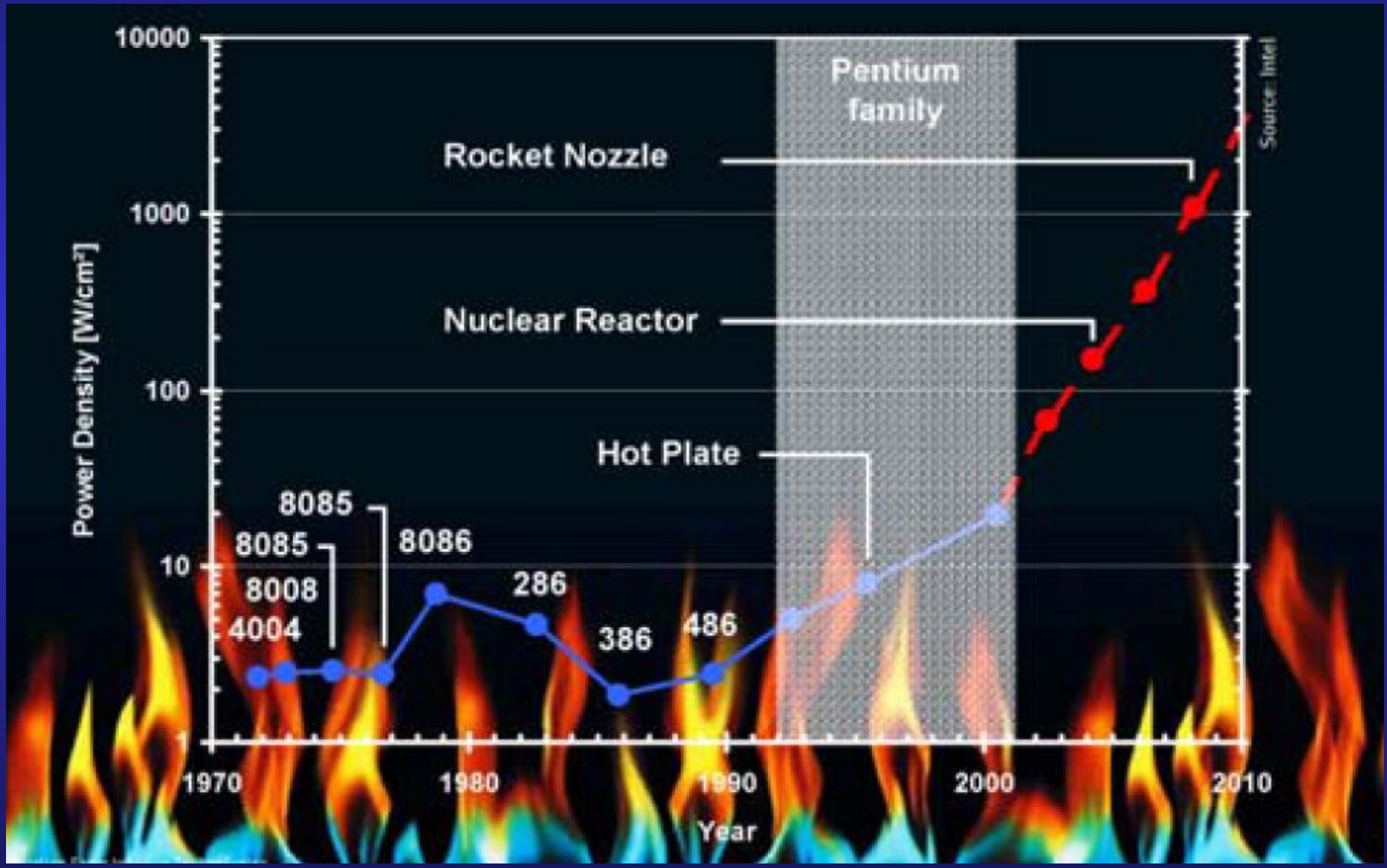
Why want more?

- Understand biology at the molecular level (protein expression, crack the DNA language,...)
- Crack secret codes
- Understand the evolution of the Universe
- Model more than “10” electrons
-
-



help Homer!

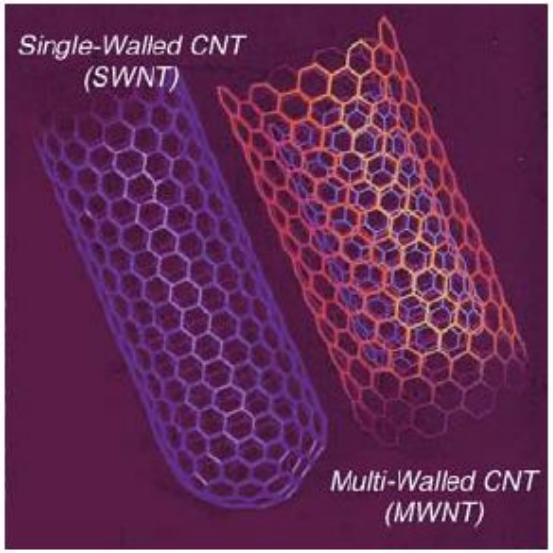
Going smaller is not good enough! (we'll burn ourselves)

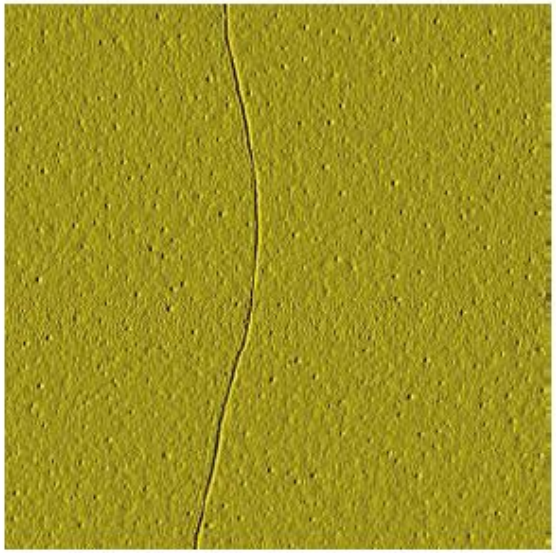


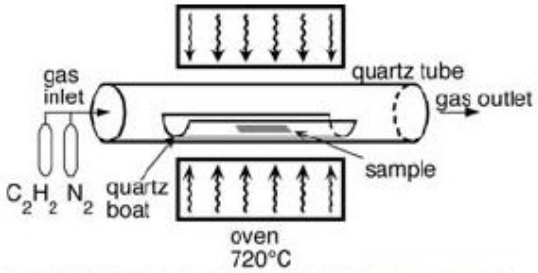
We need a new revolution! (SMALL and QUANTUM)

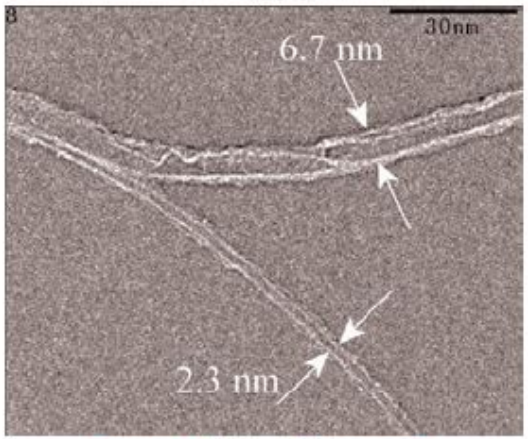
First step: SMALL (NANOtechnology)

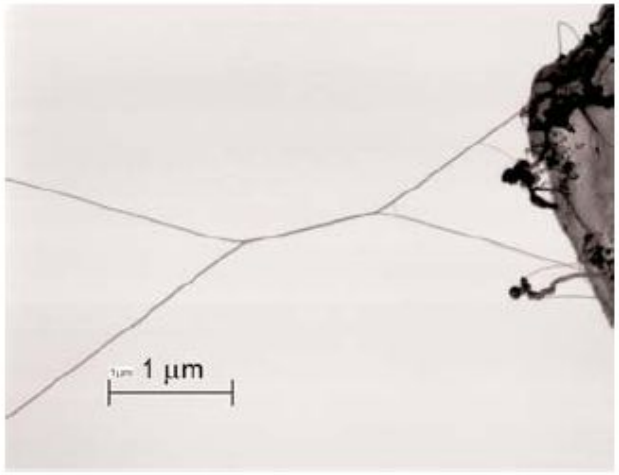
Carbon Nanotubes







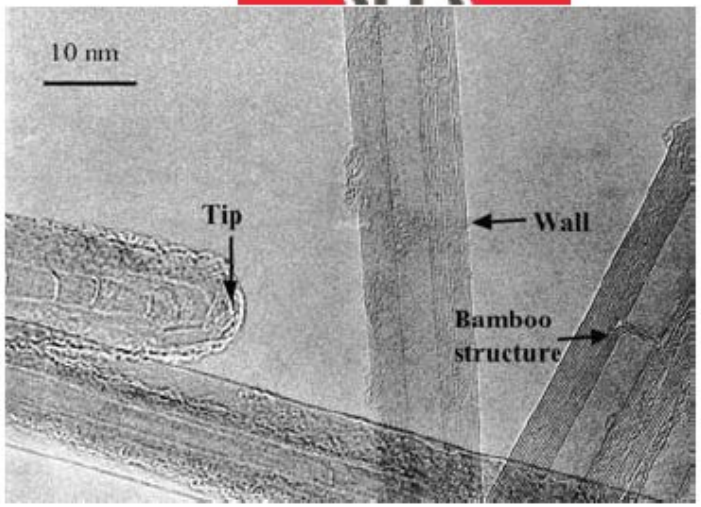




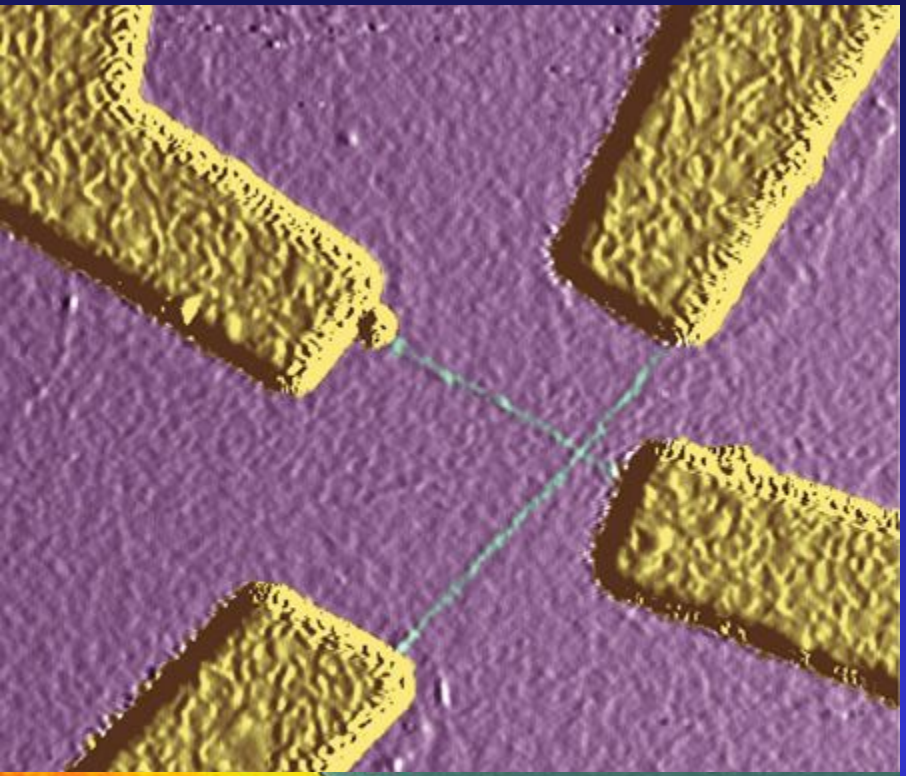
UNI BASEL

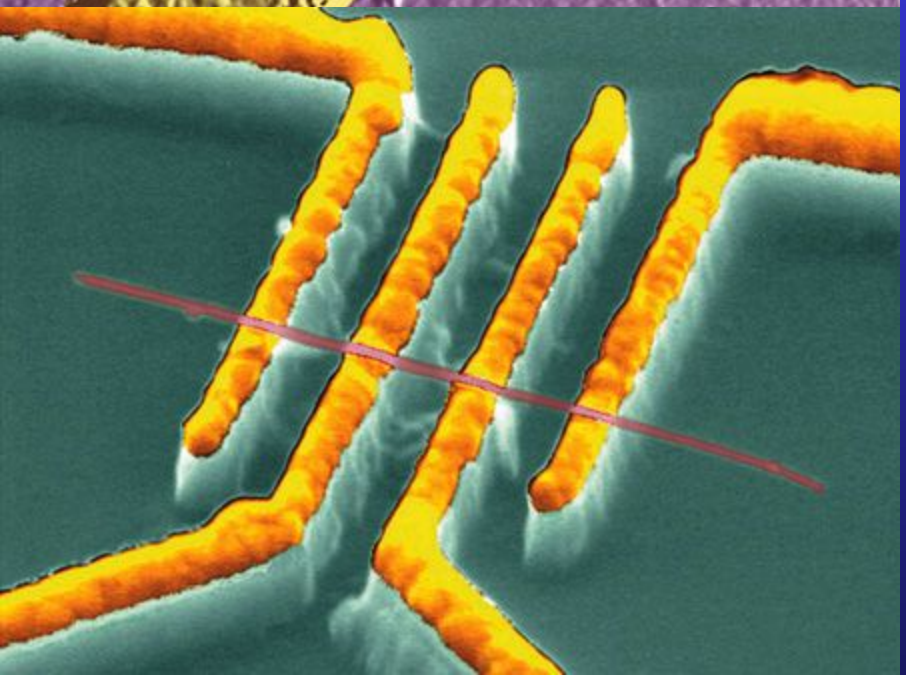
NANO

NN research group

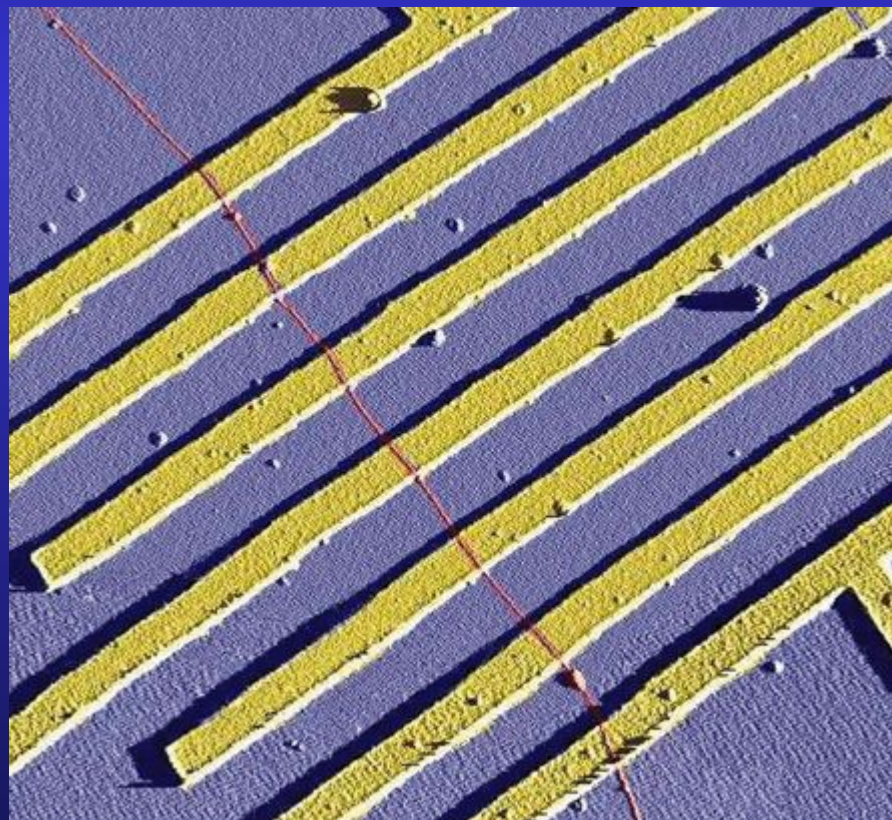


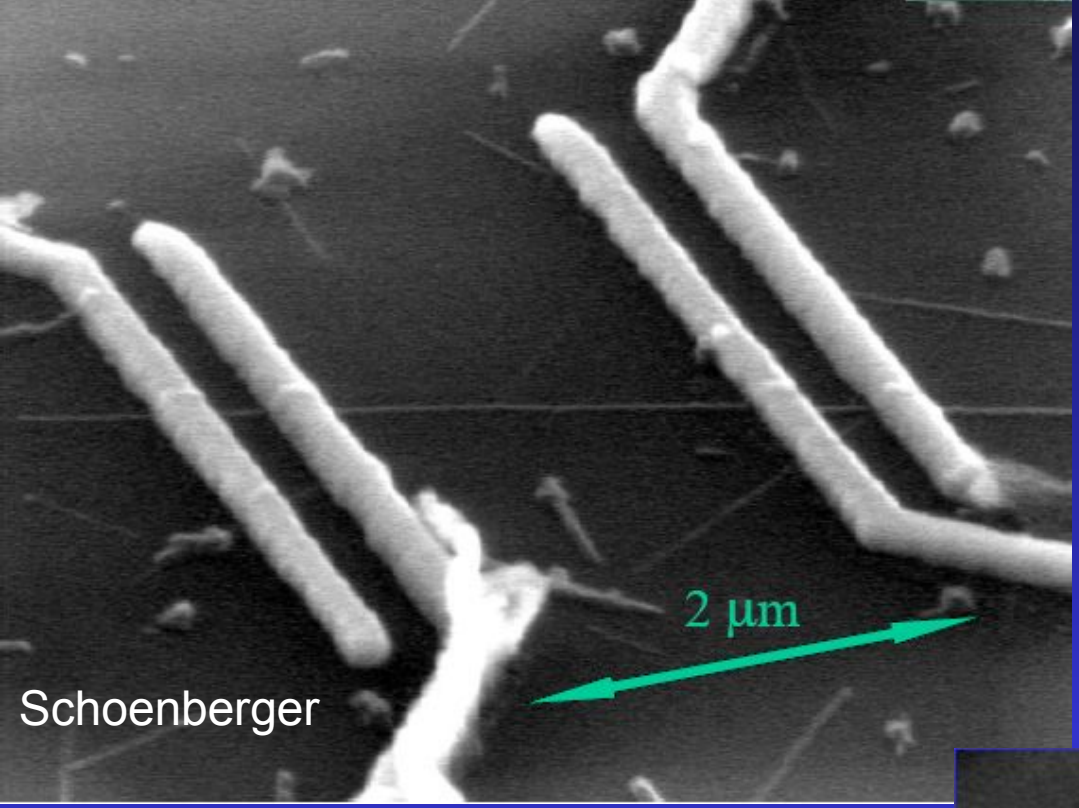
The Swiss Nanotube Consortium



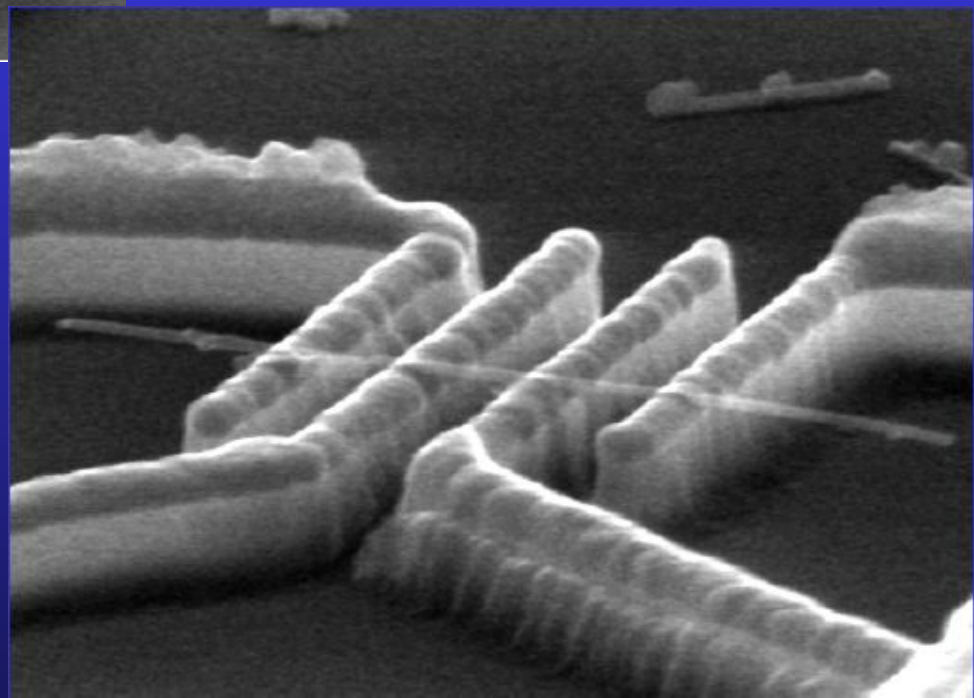


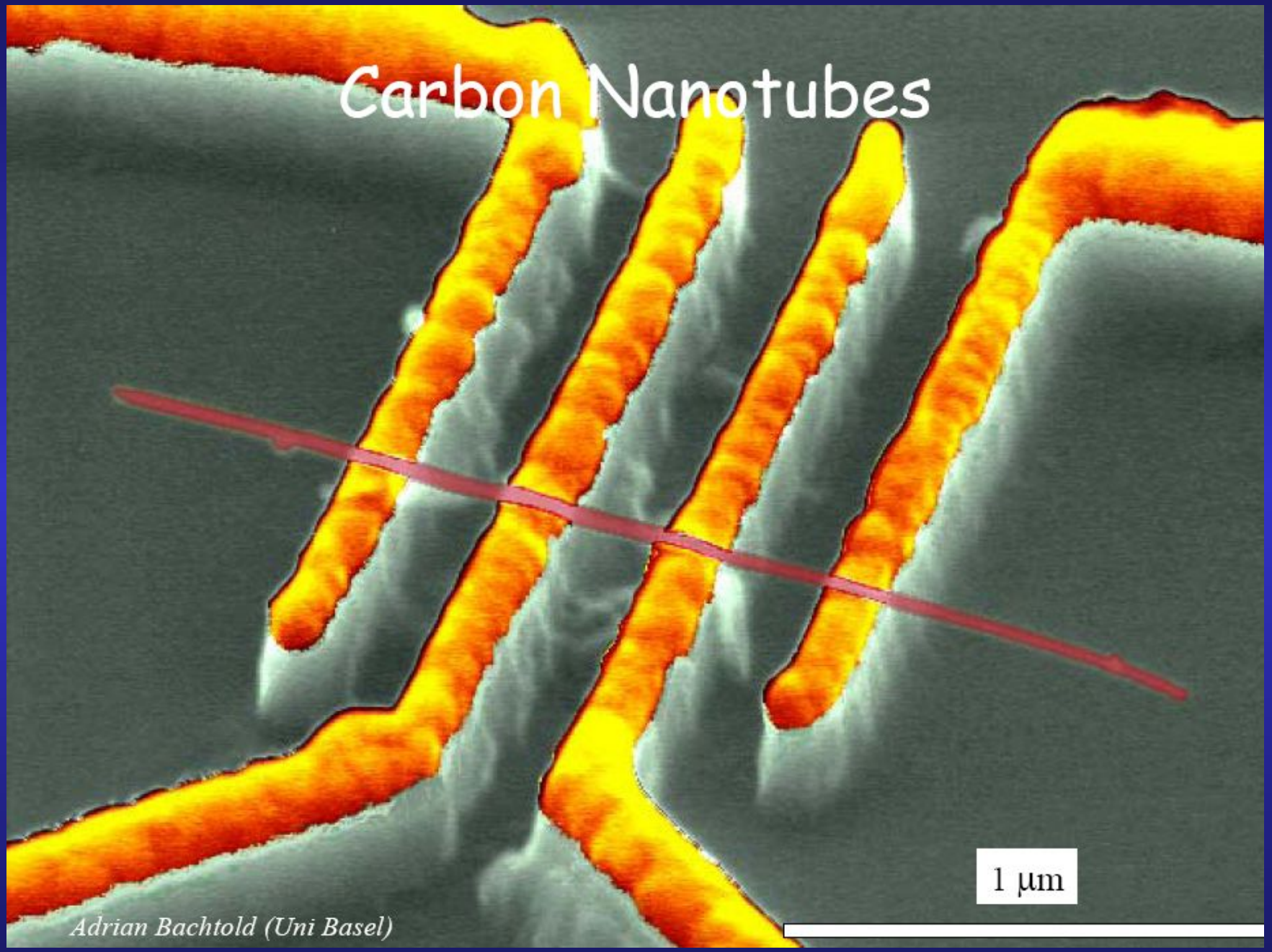
Physics World (2000)

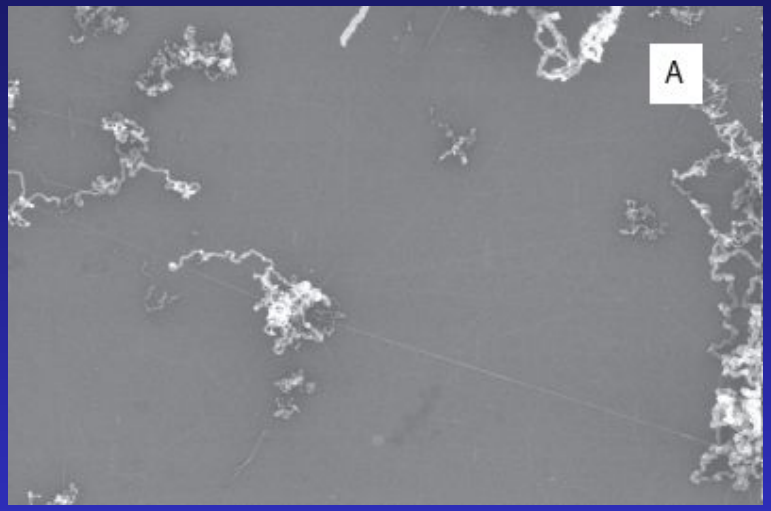


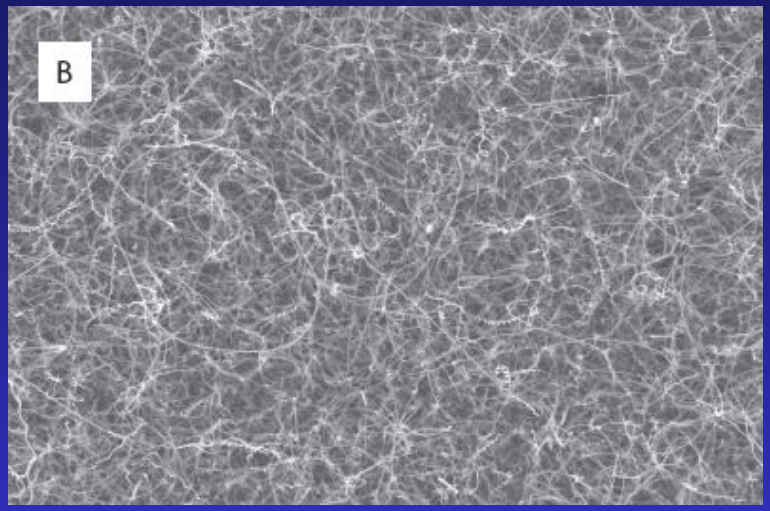


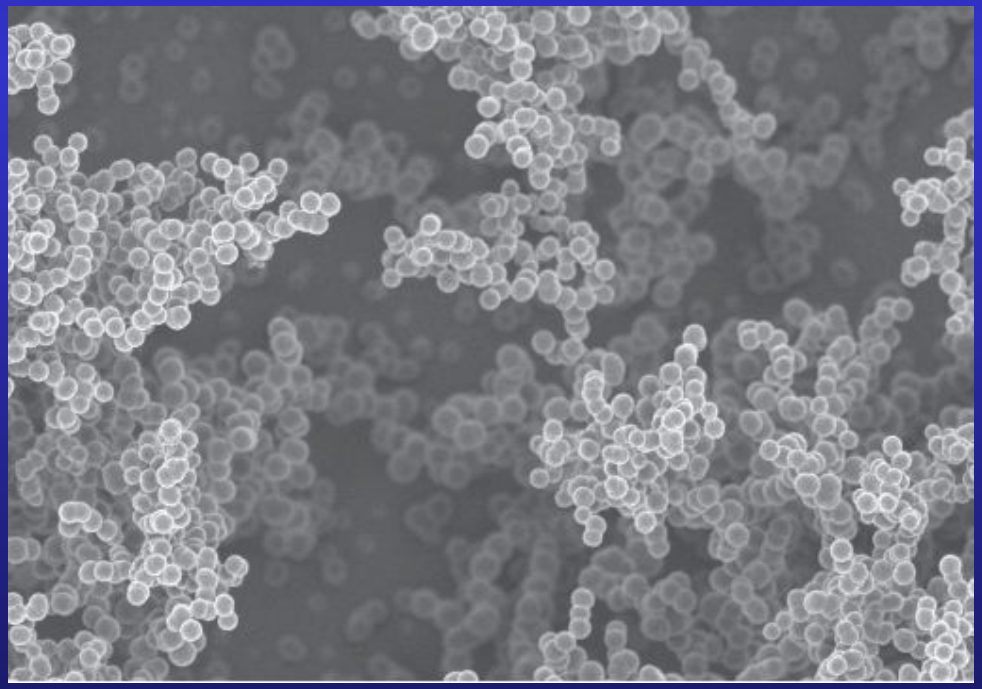
Schoenberger



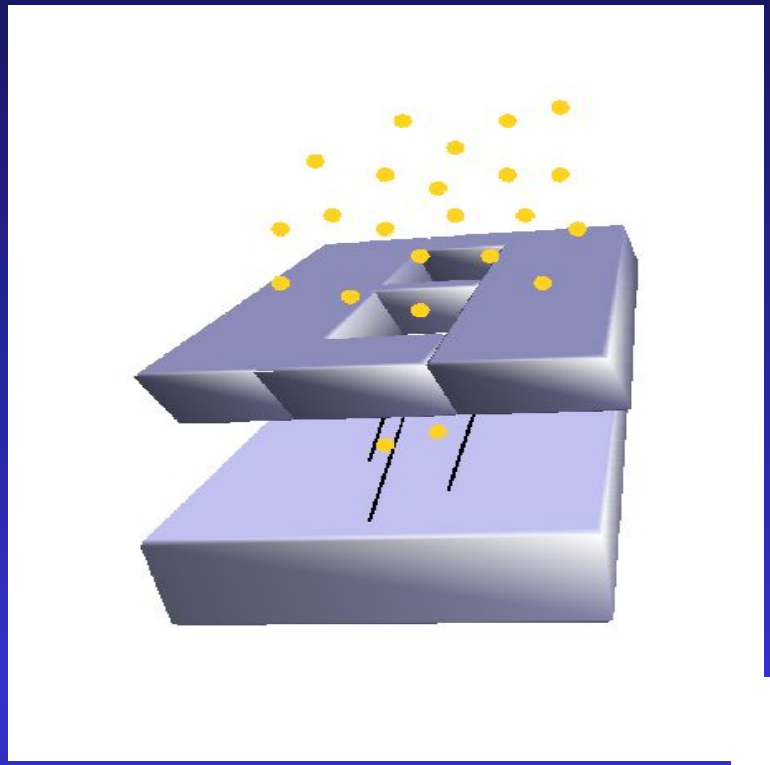

Carbon Nanotubes
1 μm
Adrian Bachtold (Uni Basel)

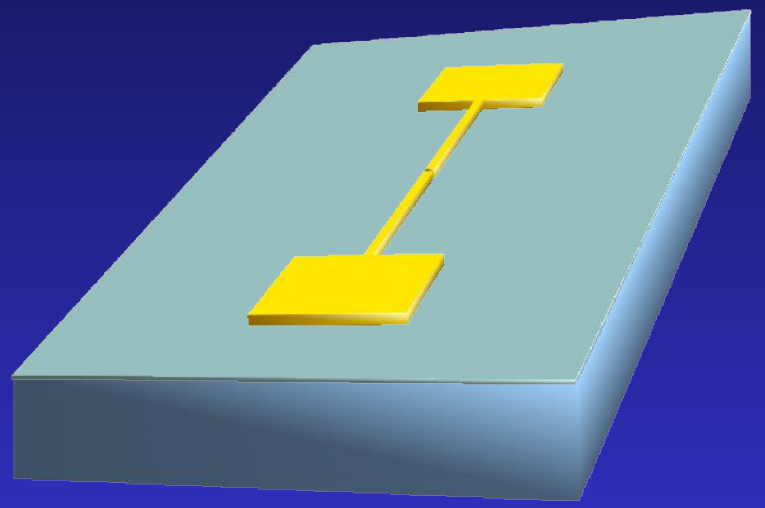




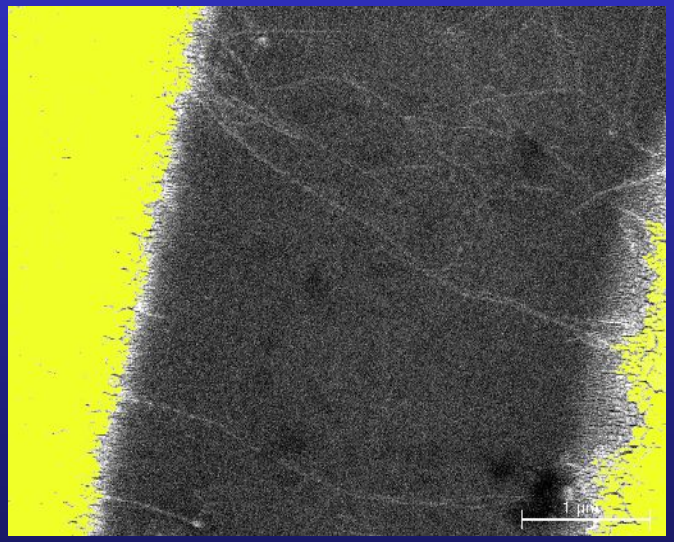


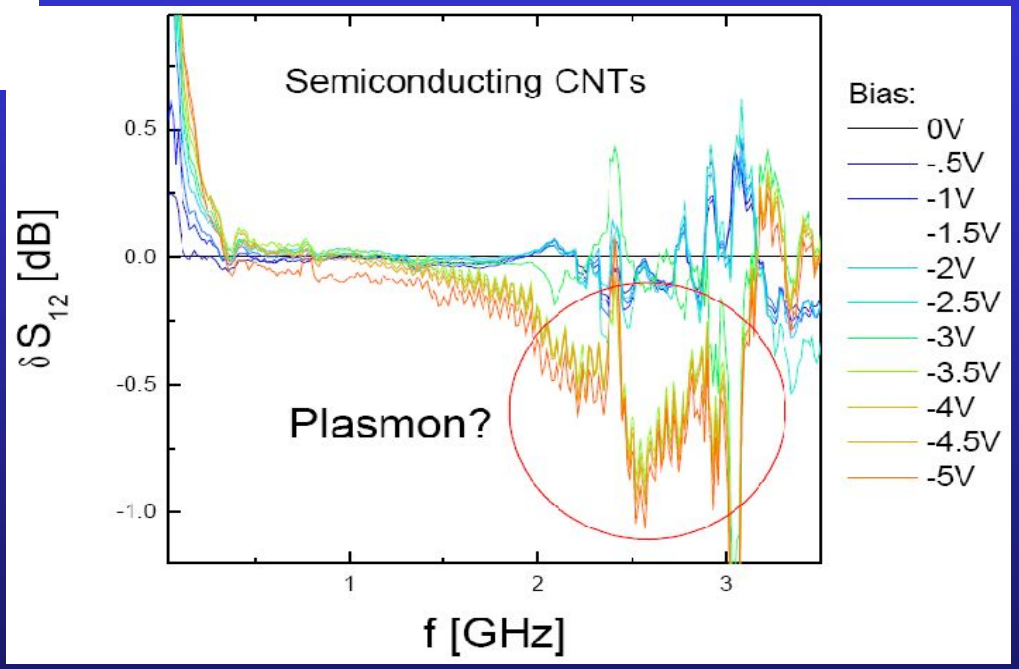
Alex Creamer

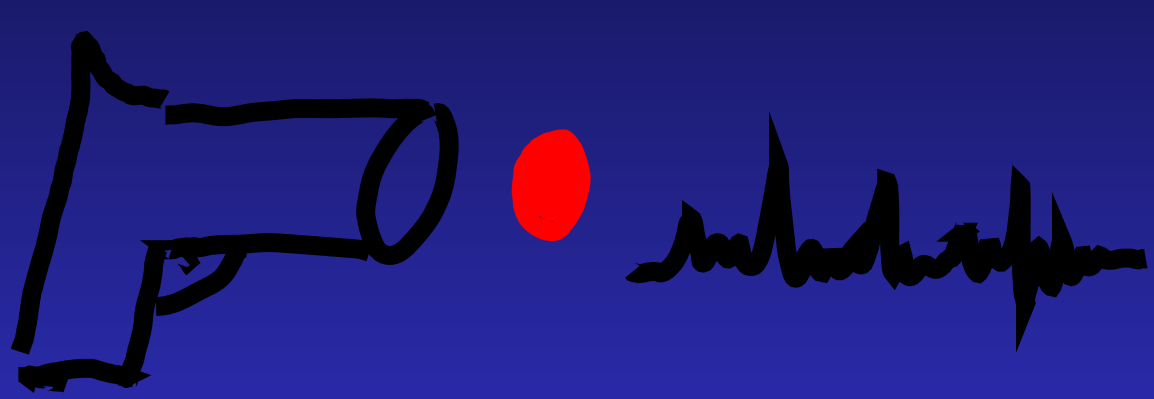




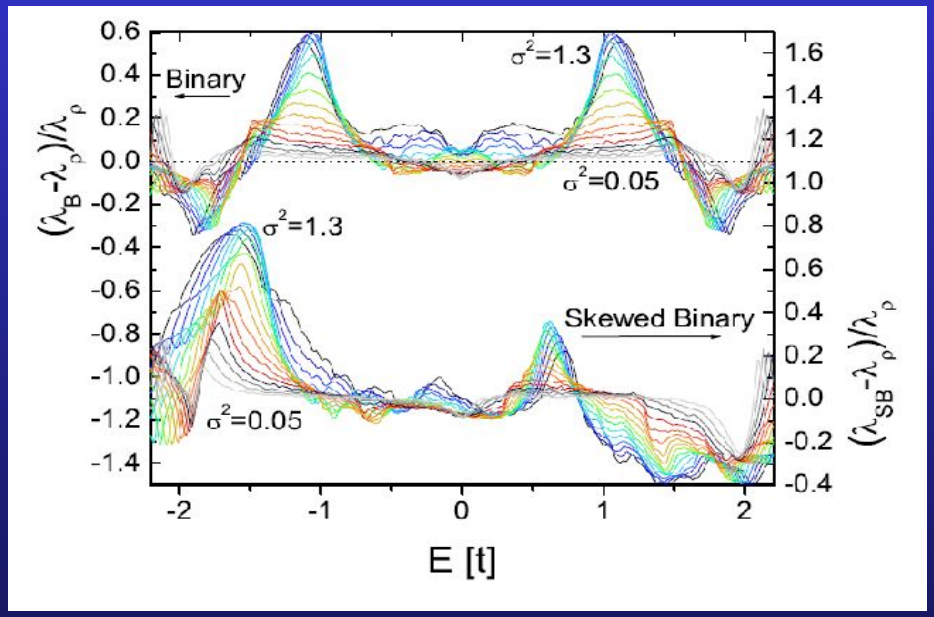
Alex Creamer





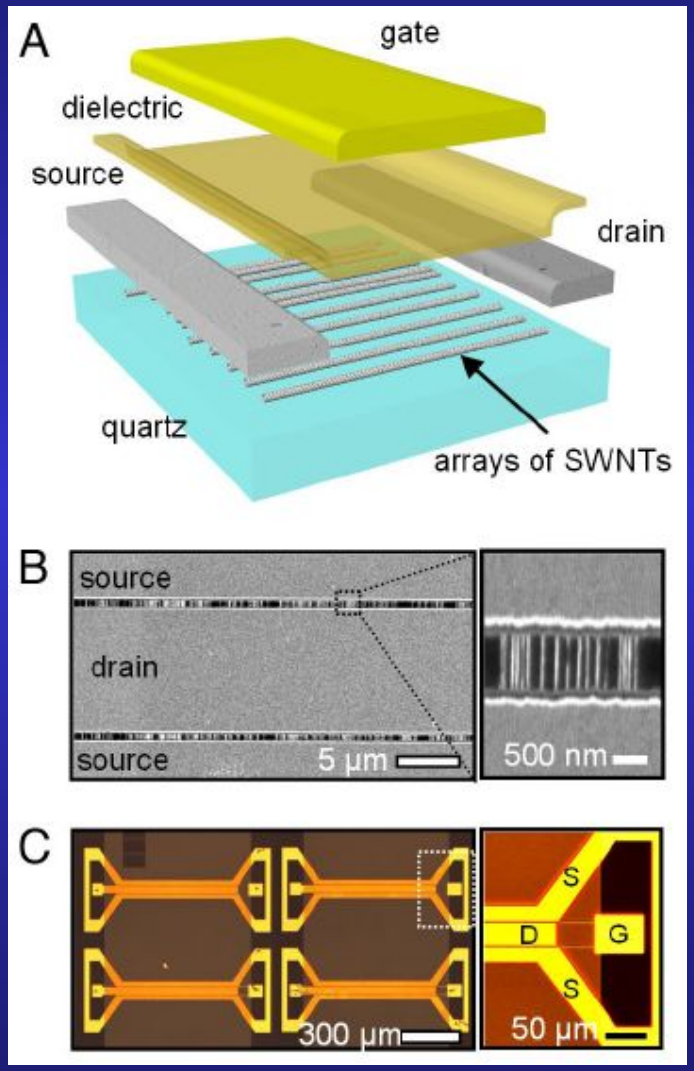


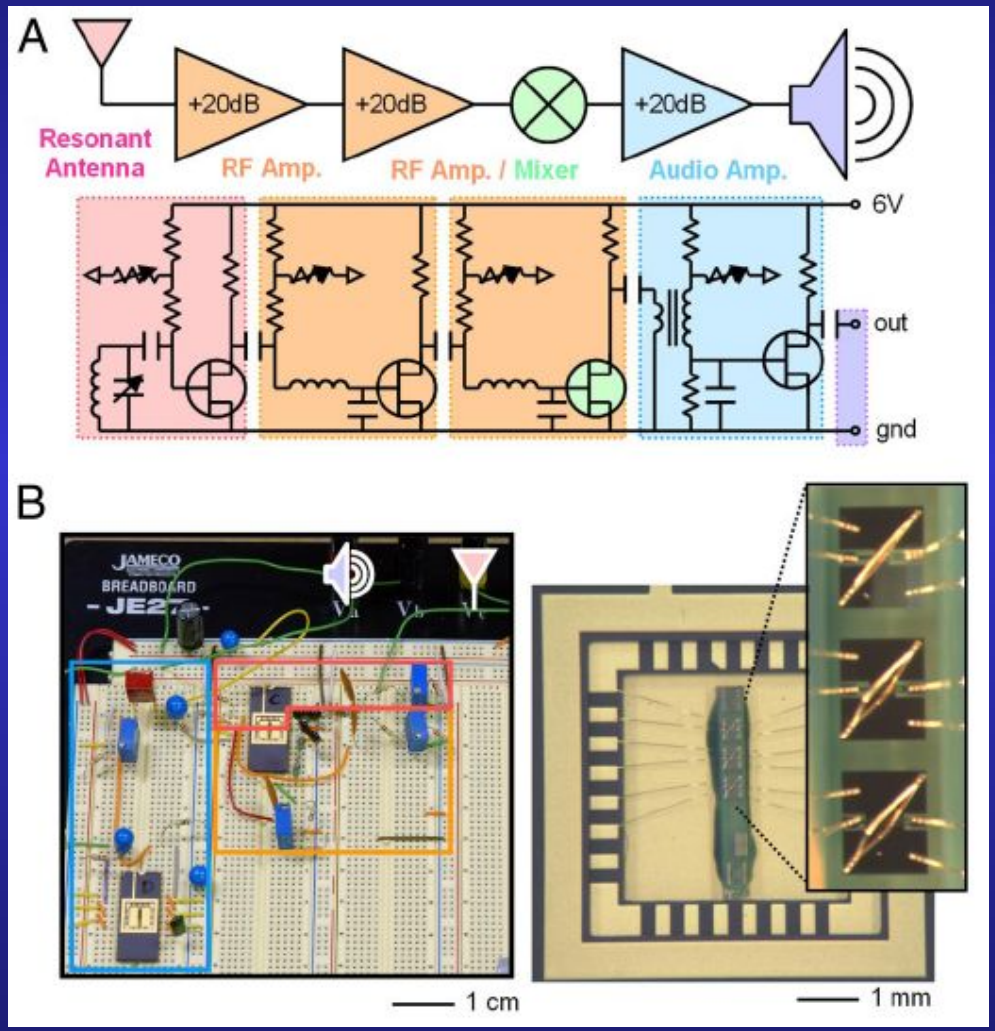
Electrons don't diffuse (Anderson localization)



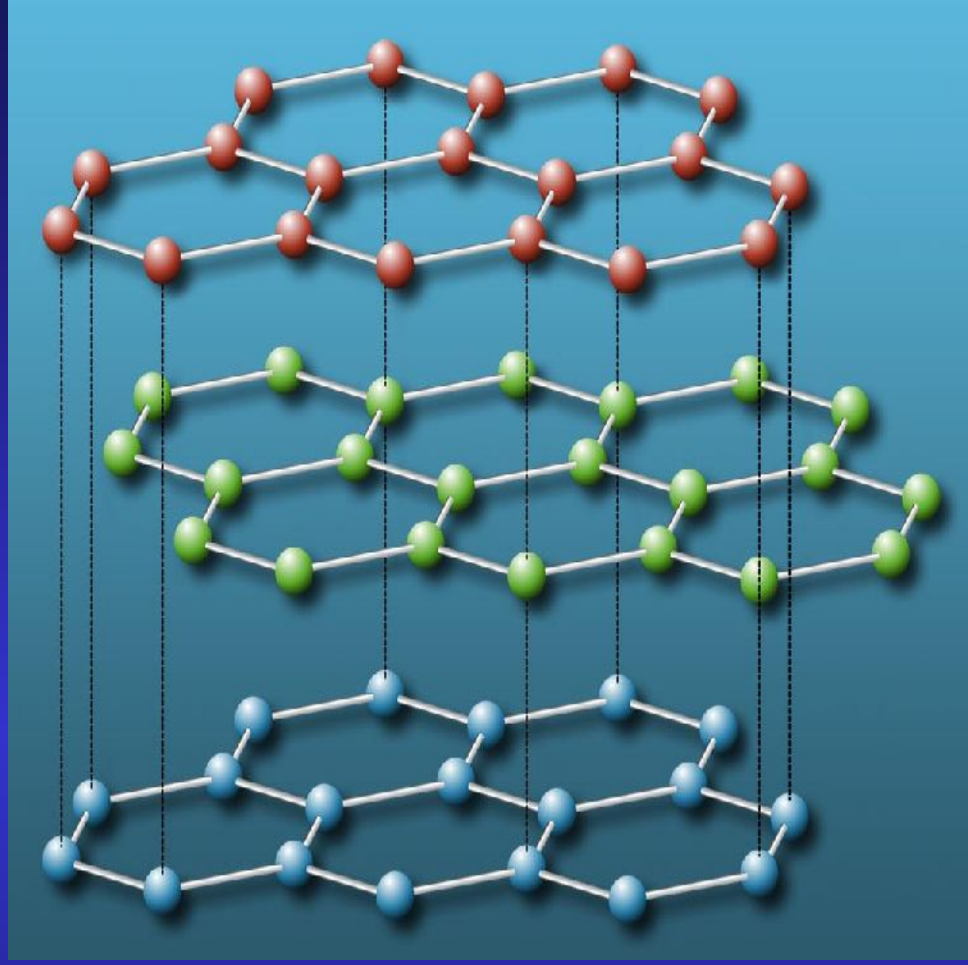
Ensemble Averaged Conductance Fluctuations (EACF)

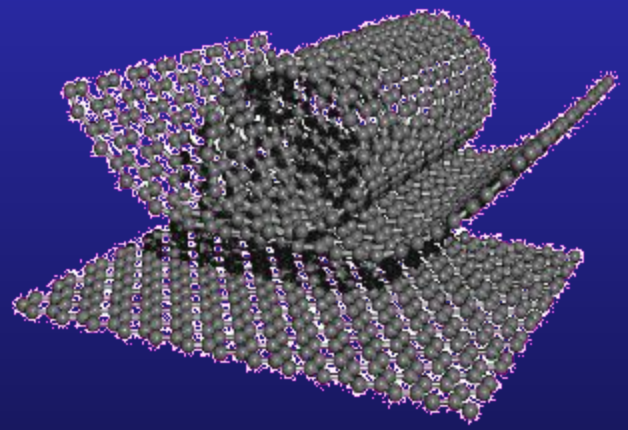
First Carbon nanotube transistor radio





Rogers, 2008





Graphite & graphene

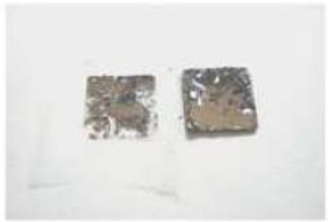
Scotch Tape Exfoliation Technique

Highly Oriented Pyrolytic Graphite (HOPG)

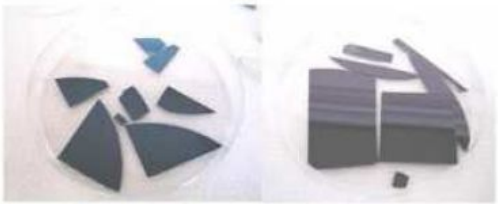
Manufactured graphite

Natural graphite (Kis

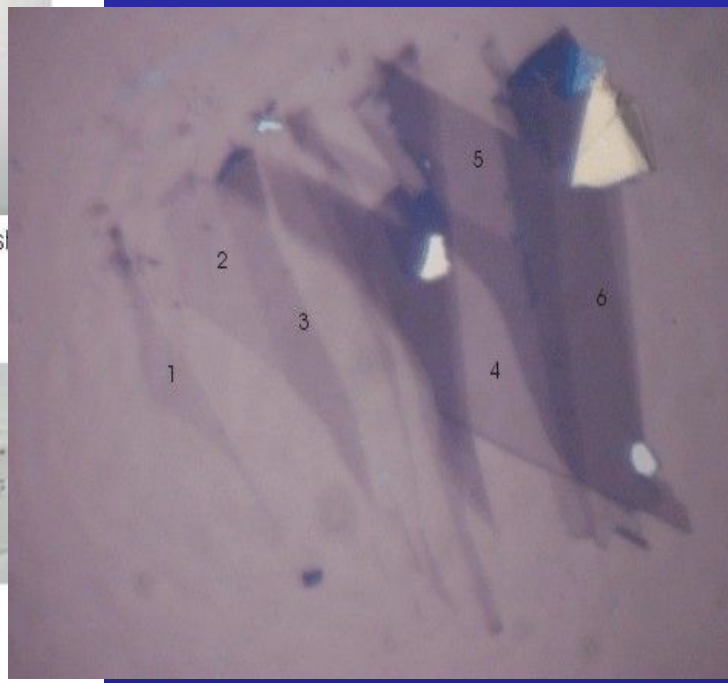
Repeatedly peeling off flakes



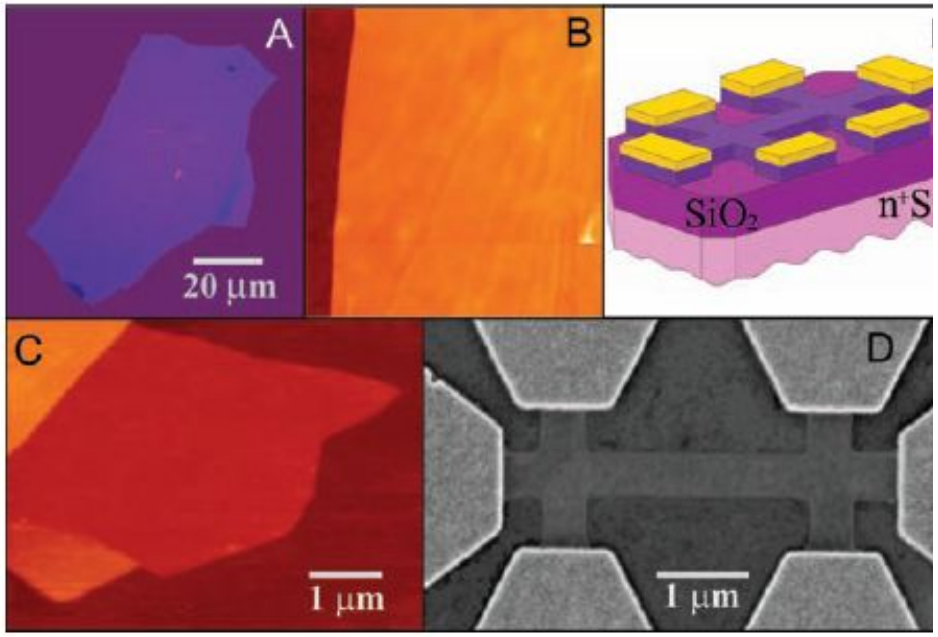
Deposited on SiO_2/Si wafer

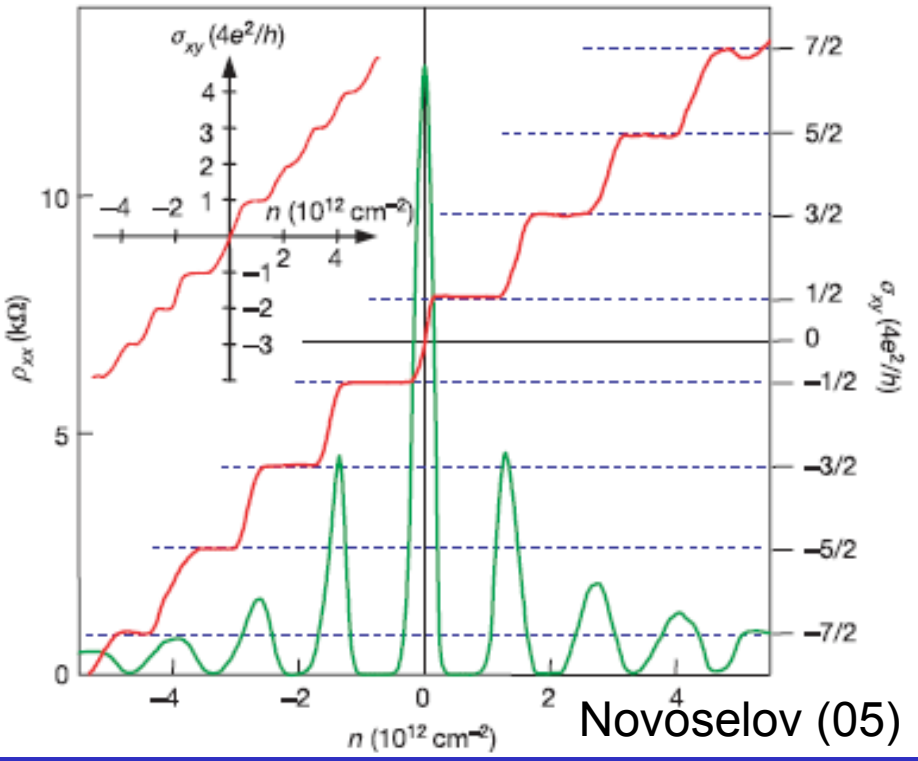


150 nm SiO_2 90 nm SiO_2

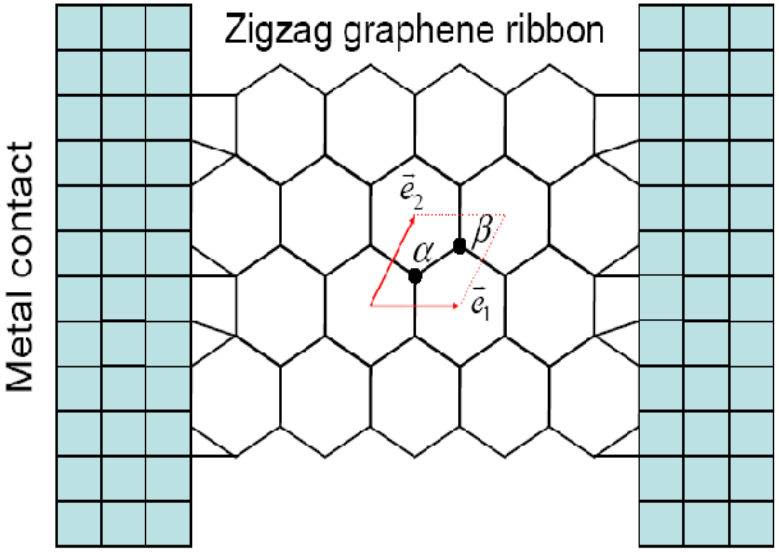


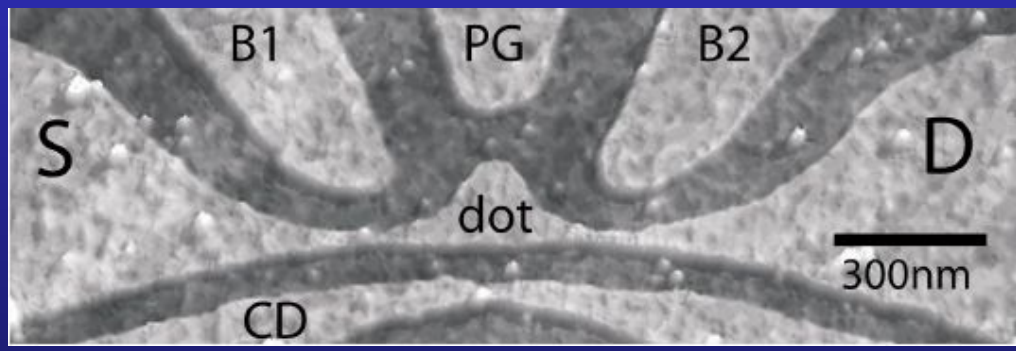
Victor Yu





Novoselov (05)





Zurich group

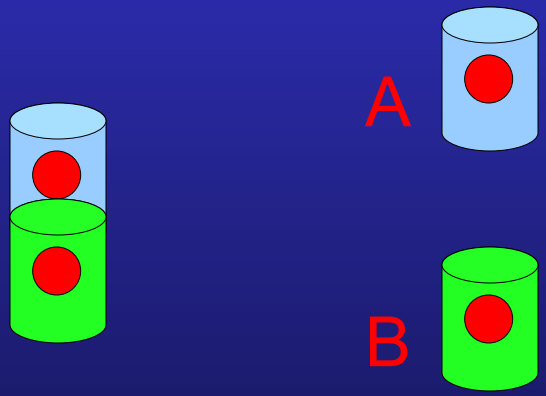
Second step: QUANTUM
(Quantum electronics)

2 fundamental aspects (no classical counterpart):

1. Ohm's law doesn't hold:

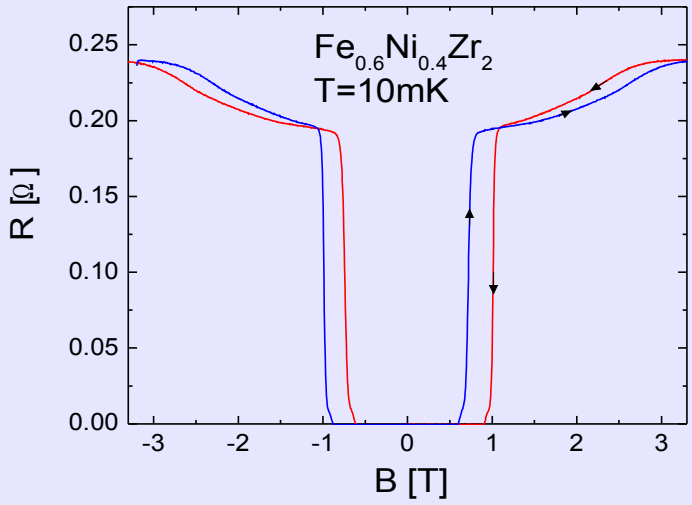
(Using Ohm's law the resistance of a 1cm*1nm*1nm gold wire would be 200MOhm)

2. Non-locality and entanglement:

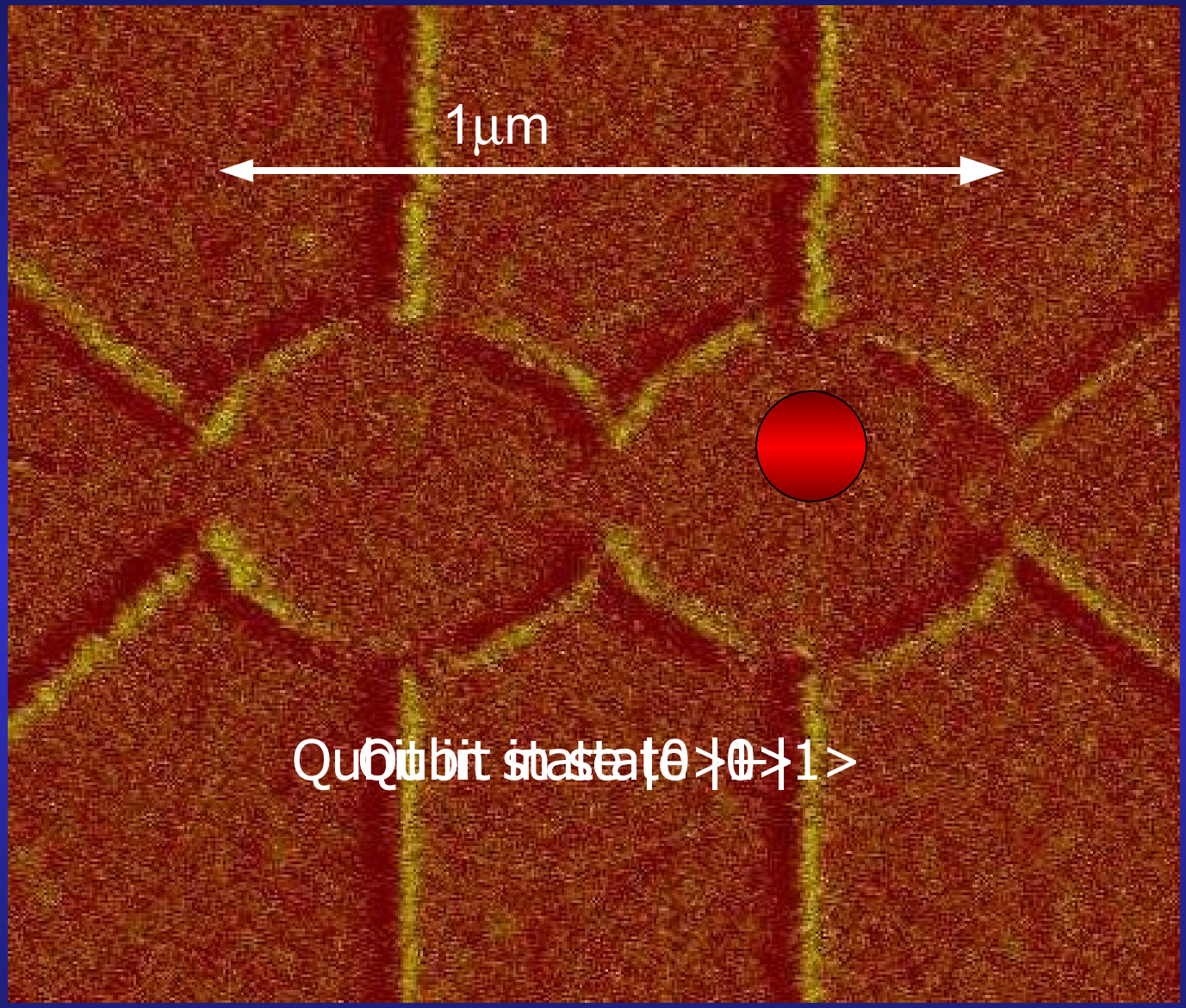


Even if separated:
A will “feel” what B is doing

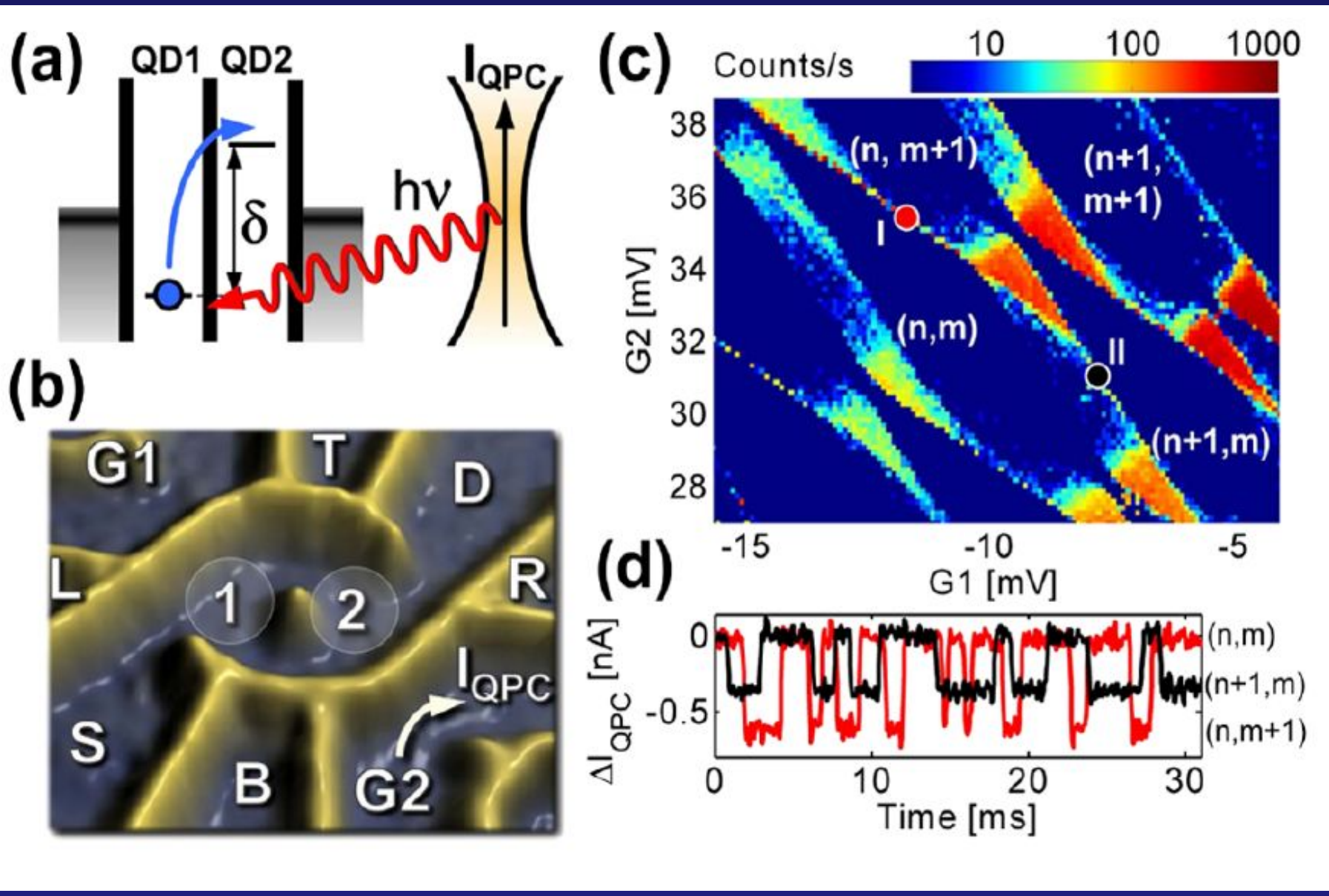
Need very low temperatures: (below 1K)



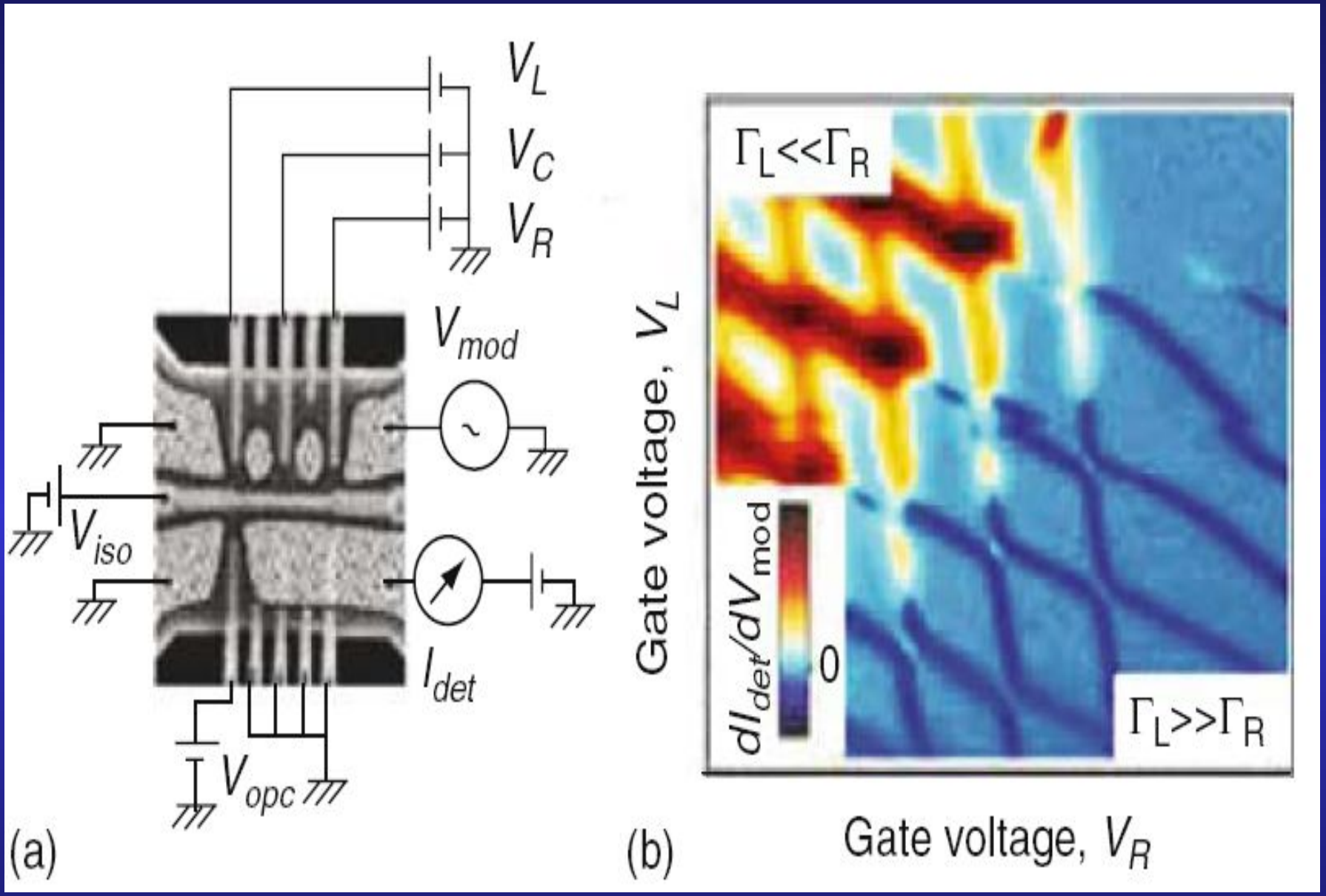
Josianne Lefebvre



Double Quantum Dots

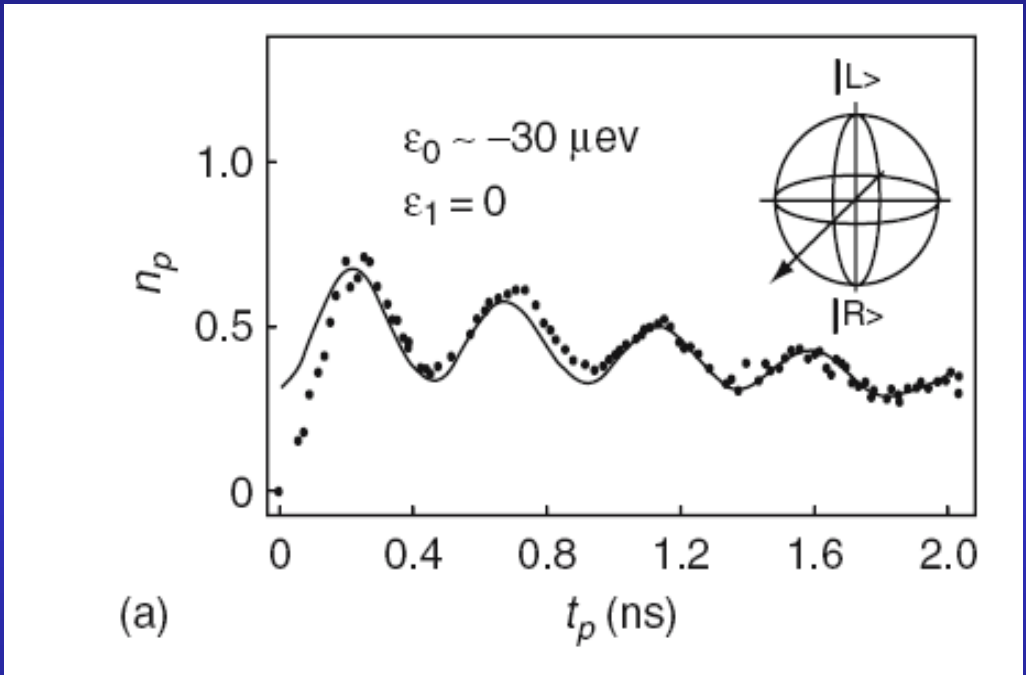


ETH group and Carolyn Young


V_L
V_C
V_R
V_{mod}
V_{iso}
I_{det}
V_{opc}
(a)
$\Gamma_L << \Gamma_R$
$\Gamma_L >> \Gamma_R$
dI_{det}/dV_{mod}
0
Gate voltage, V_L
Gate voltage, V_R
(b)

NTT group

Need very high speeds too...



NTT group

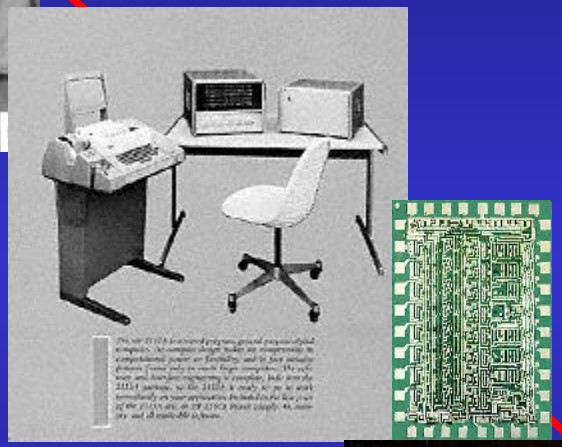
Quantum coherent oscillations between two states

History

1947: first transistor

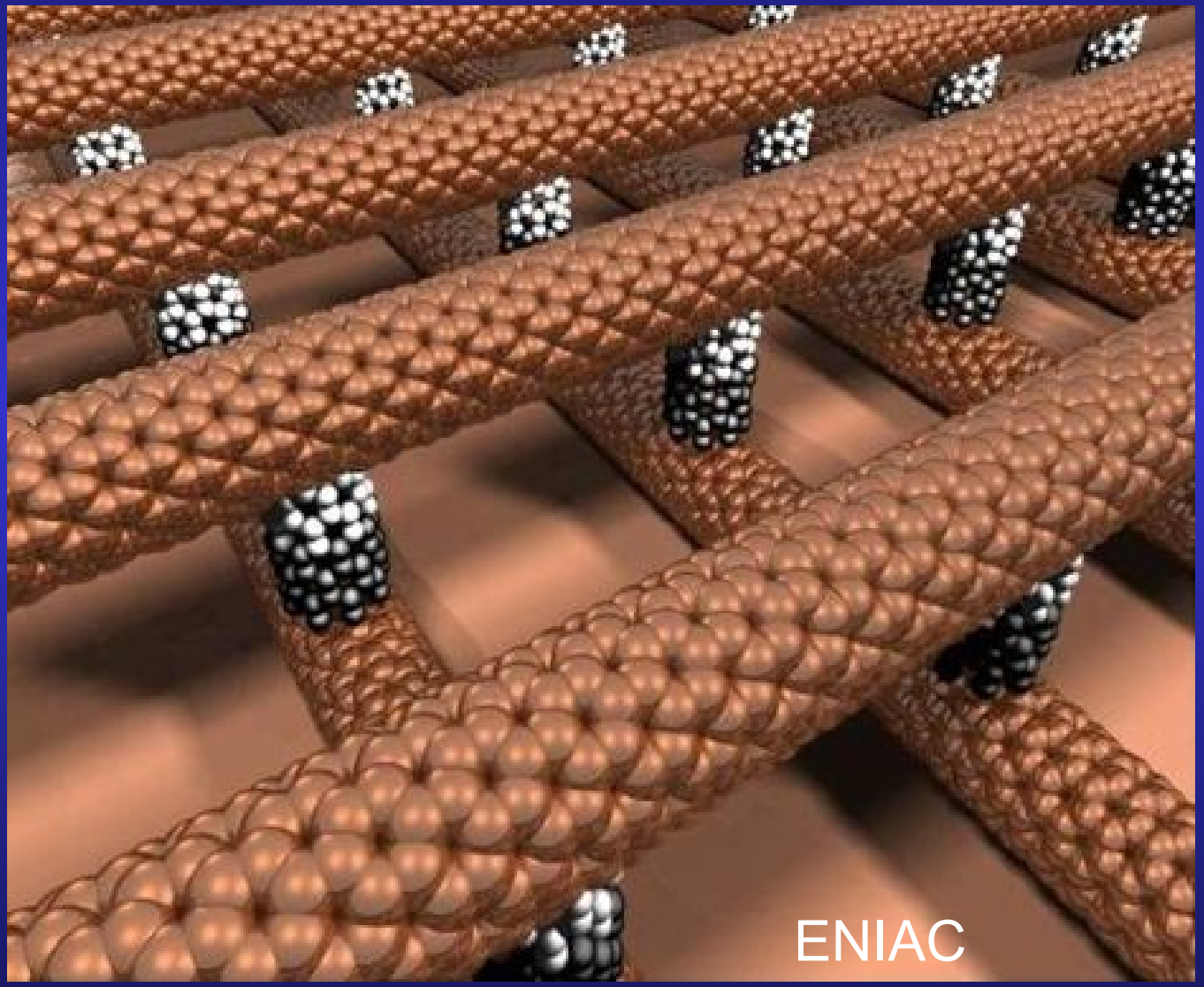
1958: first IC (Kilby)

1966: first Office computer (HP-2115)



1977: first PC (Apple II)

Is this the future?



Homer is saved!

McGill