NANOTECNOLOGIA:

O canal entre o macro e o nano

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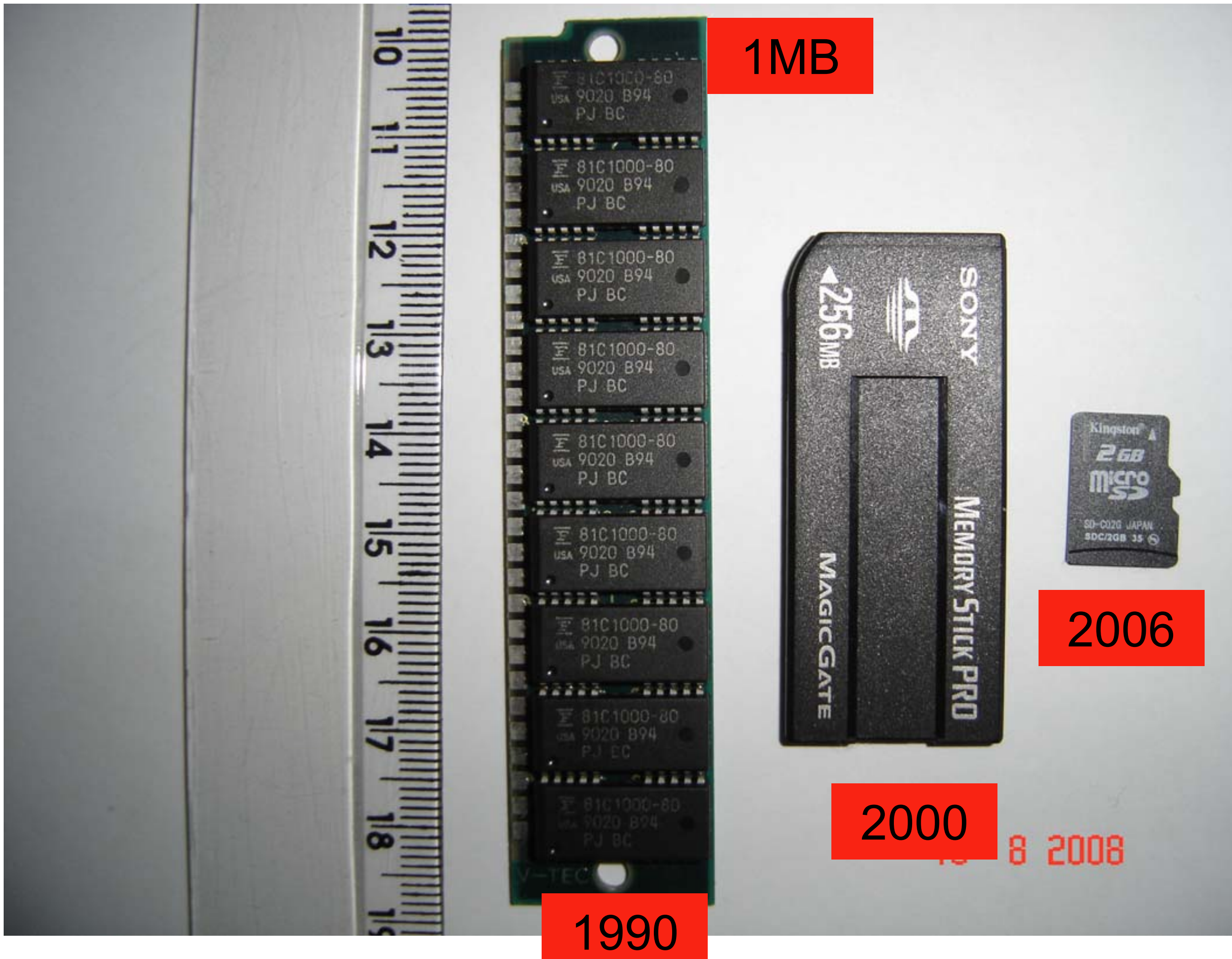
O IMPACTO DA NANOTECNOLOGIA

NO DIA-A-DIA

EXEMPLOS:

EVOLUÇÃO DO ARMAZENAMENTO EM MEMÓRIAS “FLASH”



EVOLUÇÃO DO ARMAZENAMENTO EM DISCOS

CD – AUDIO (600 MB)

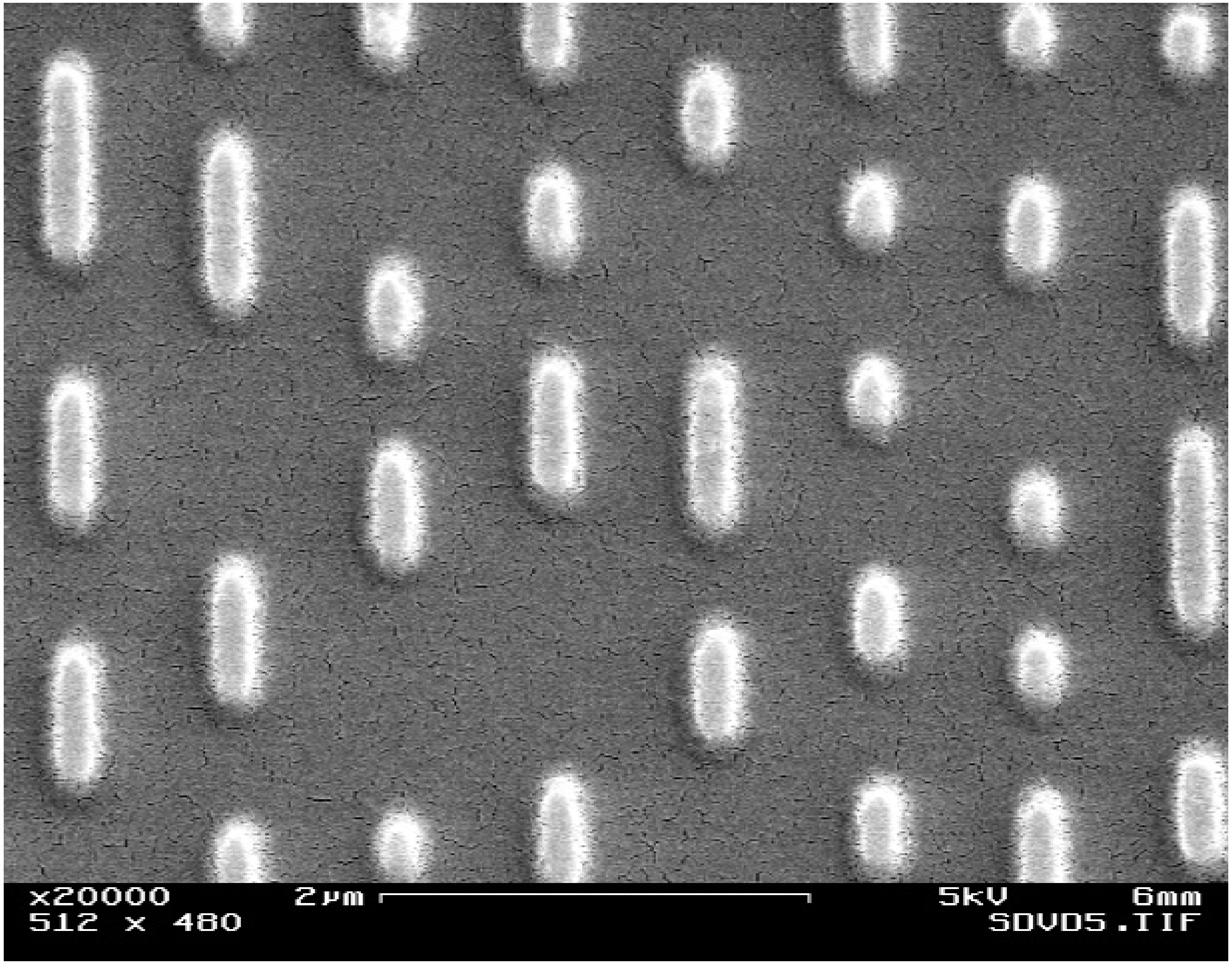
DVD – AUDIO E VIDEO (4-8 GB)

BLU-RAY – VIDEO DE ALTA-DEFINIÇÃO (25Gb – 50GB)

1MB – 10^6 bytes (1.000.000)

2GB – 10^9 bytes (1.000.000.000)

MICROSCOPIA ELETRÔNICA - CD

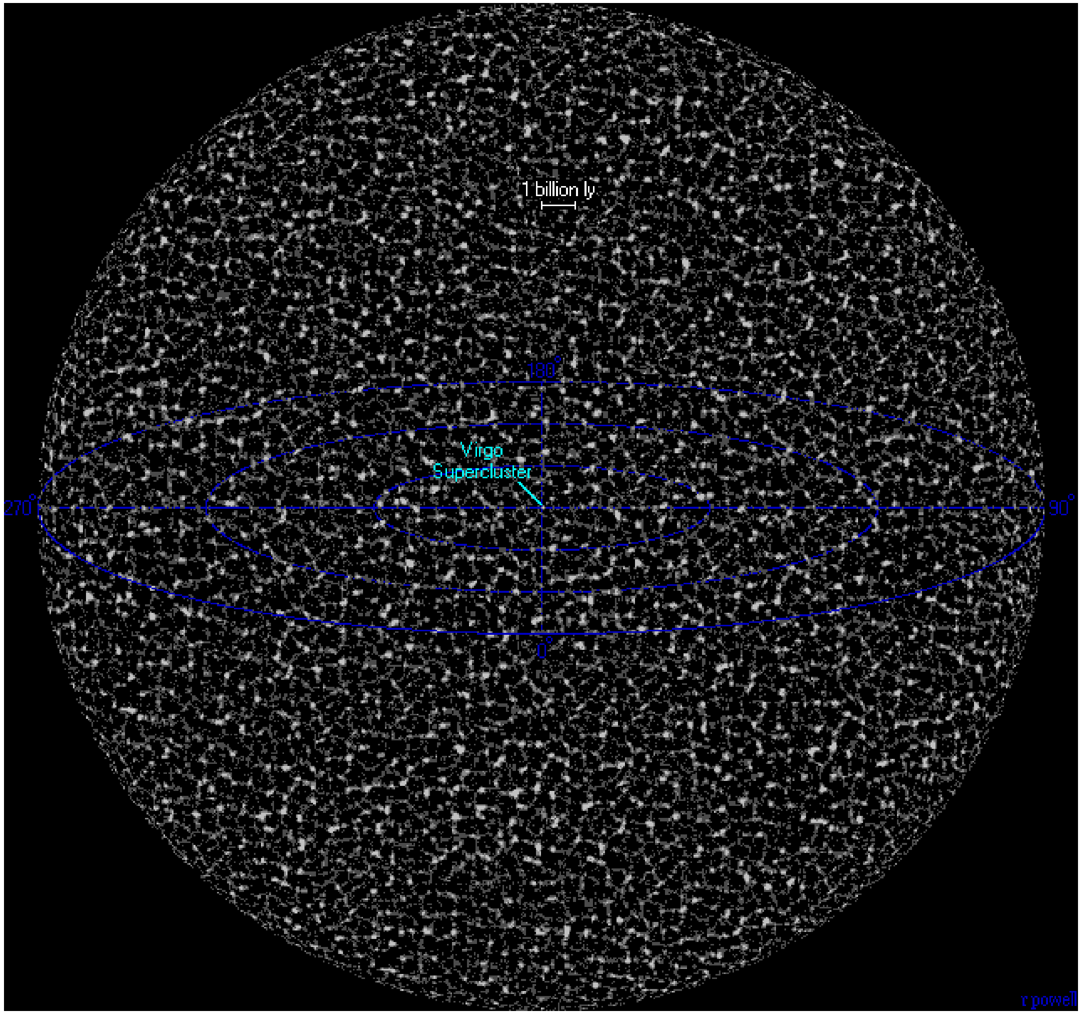


ESCALAS DE TAMANHO

Definição de metro:

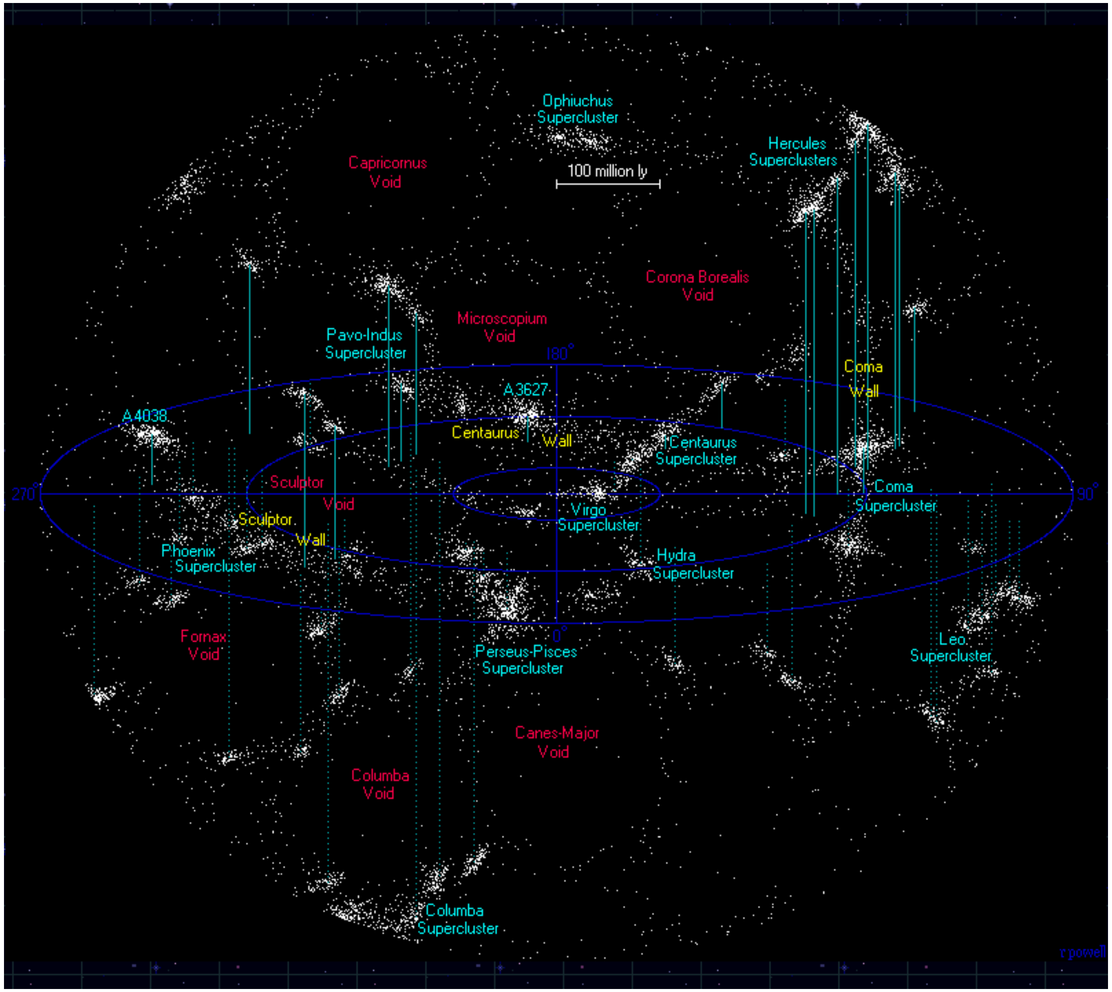
"o metro é definido como sendo o comprimento do trajeto percorrido pela luz no vácuo, durante um intervalo de tempo de 1/299792458 de segundo"

UMA VIAGEM PELO UNIVERSO

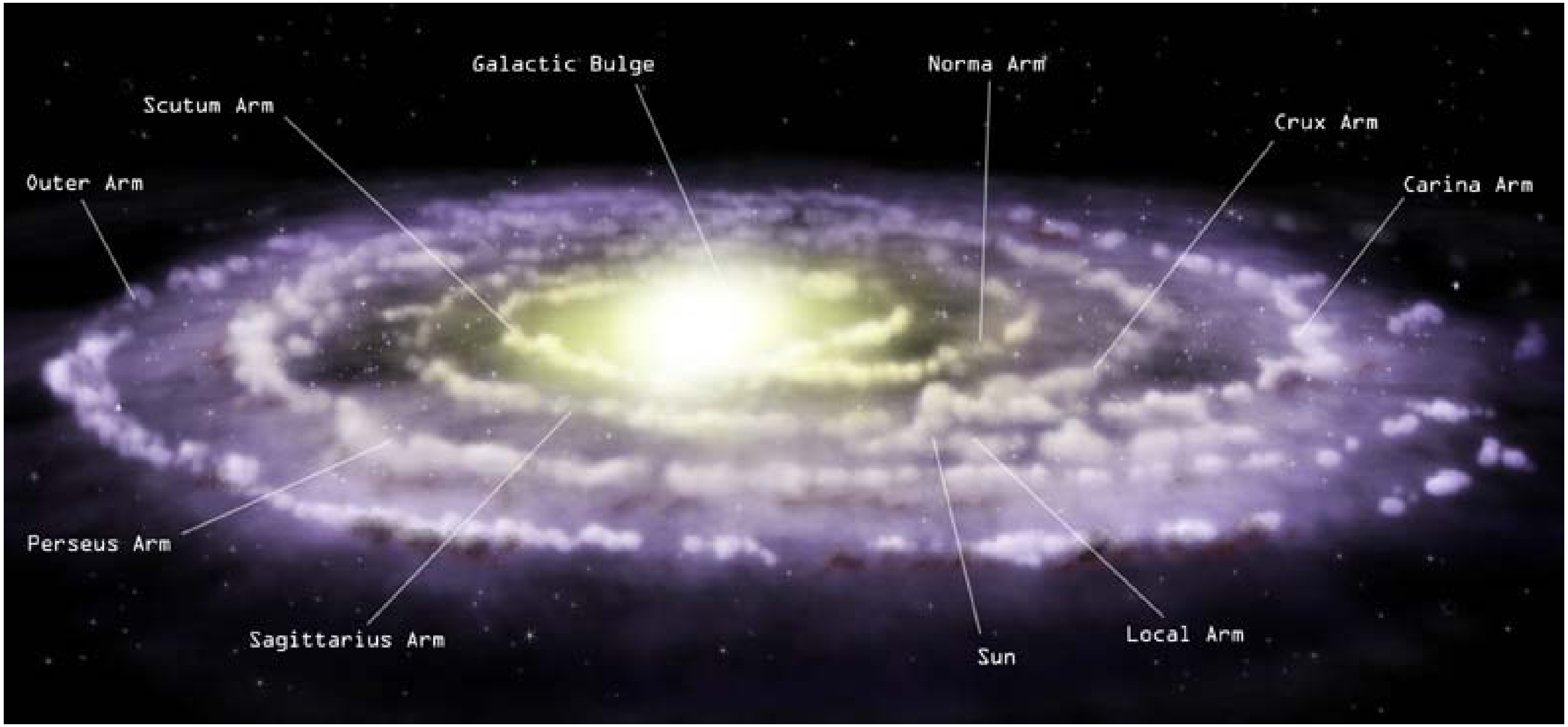


1 ano-luz = $9{,}5\times10^{15}$m = 9.500.000.000.000.000 m

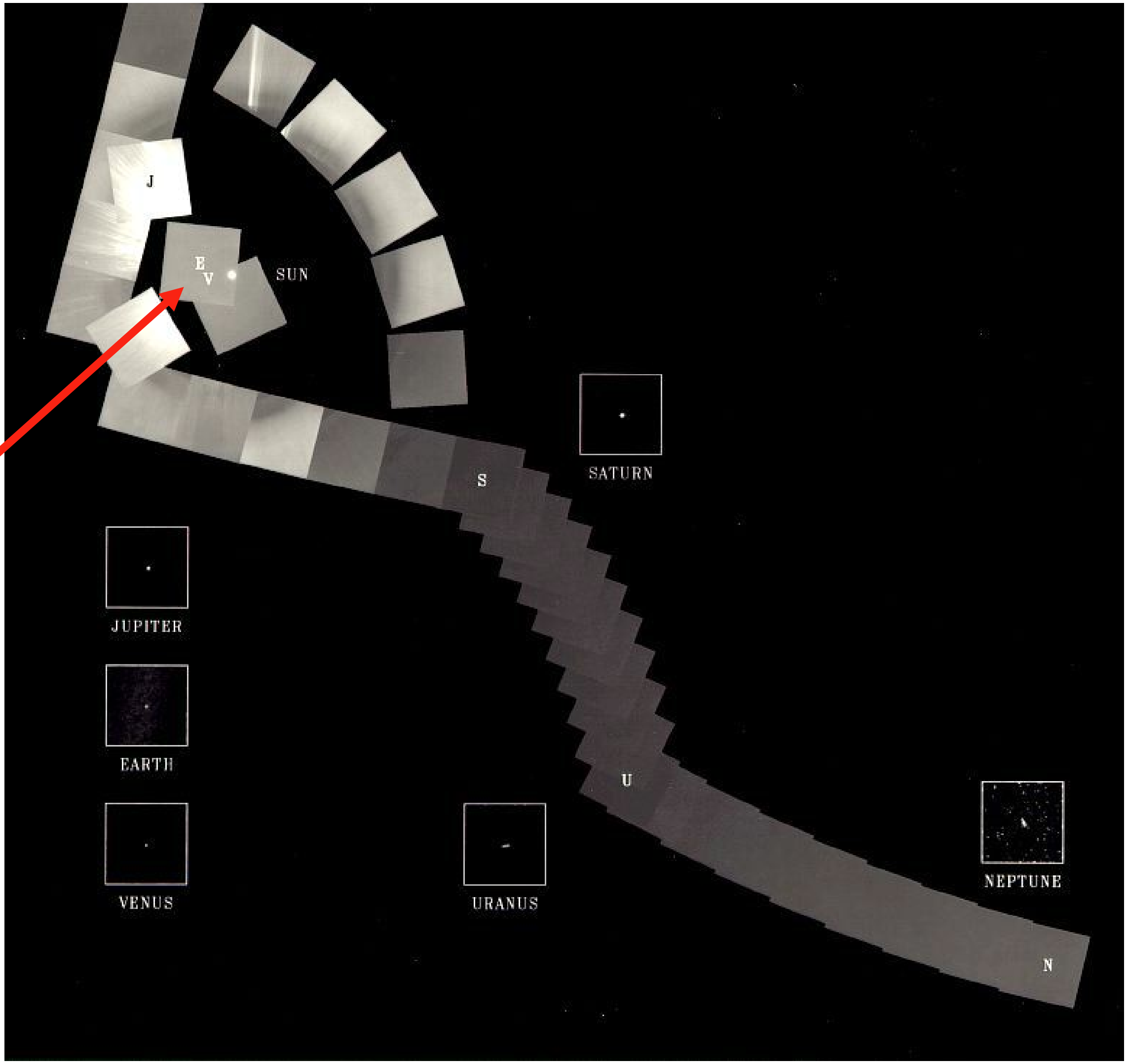
ONDE ESTAMOS?



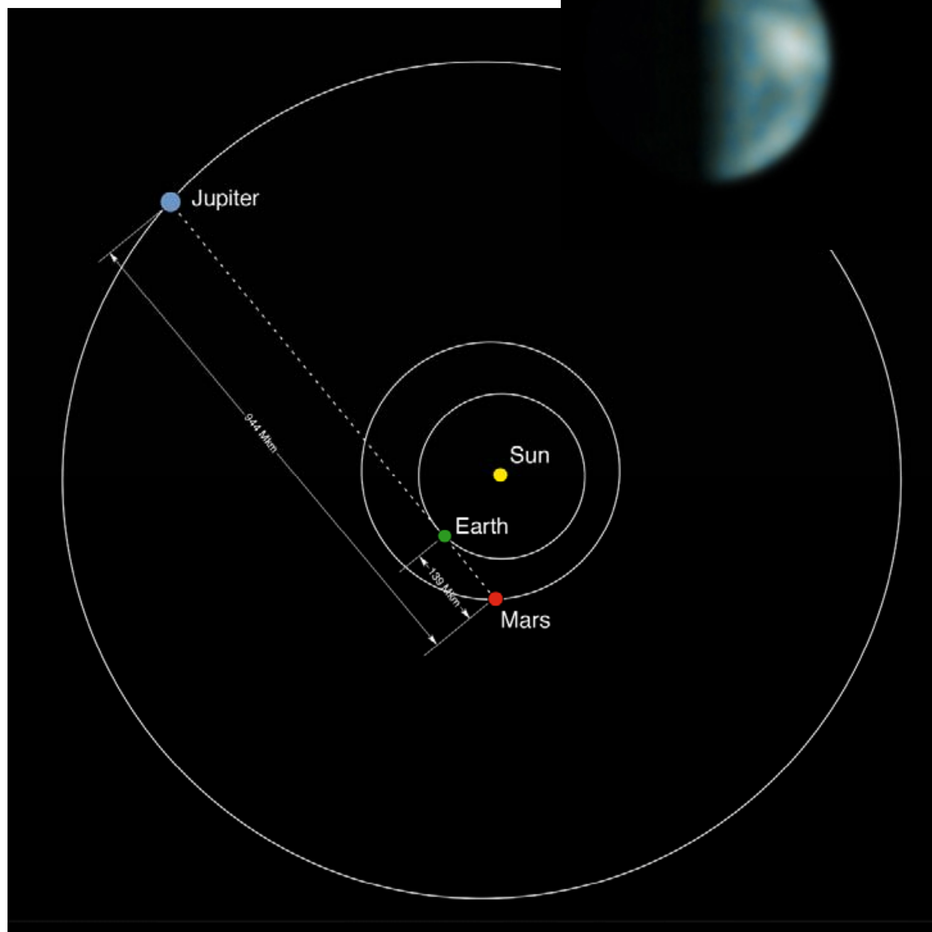
NOSSA GALAXIA – O SOL

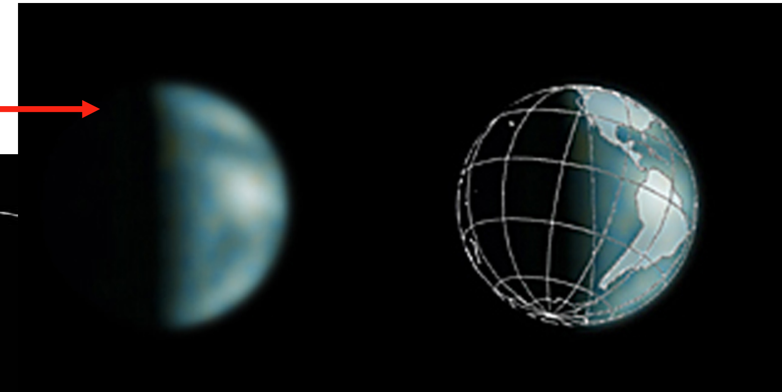


ONDE ESTAMOS?



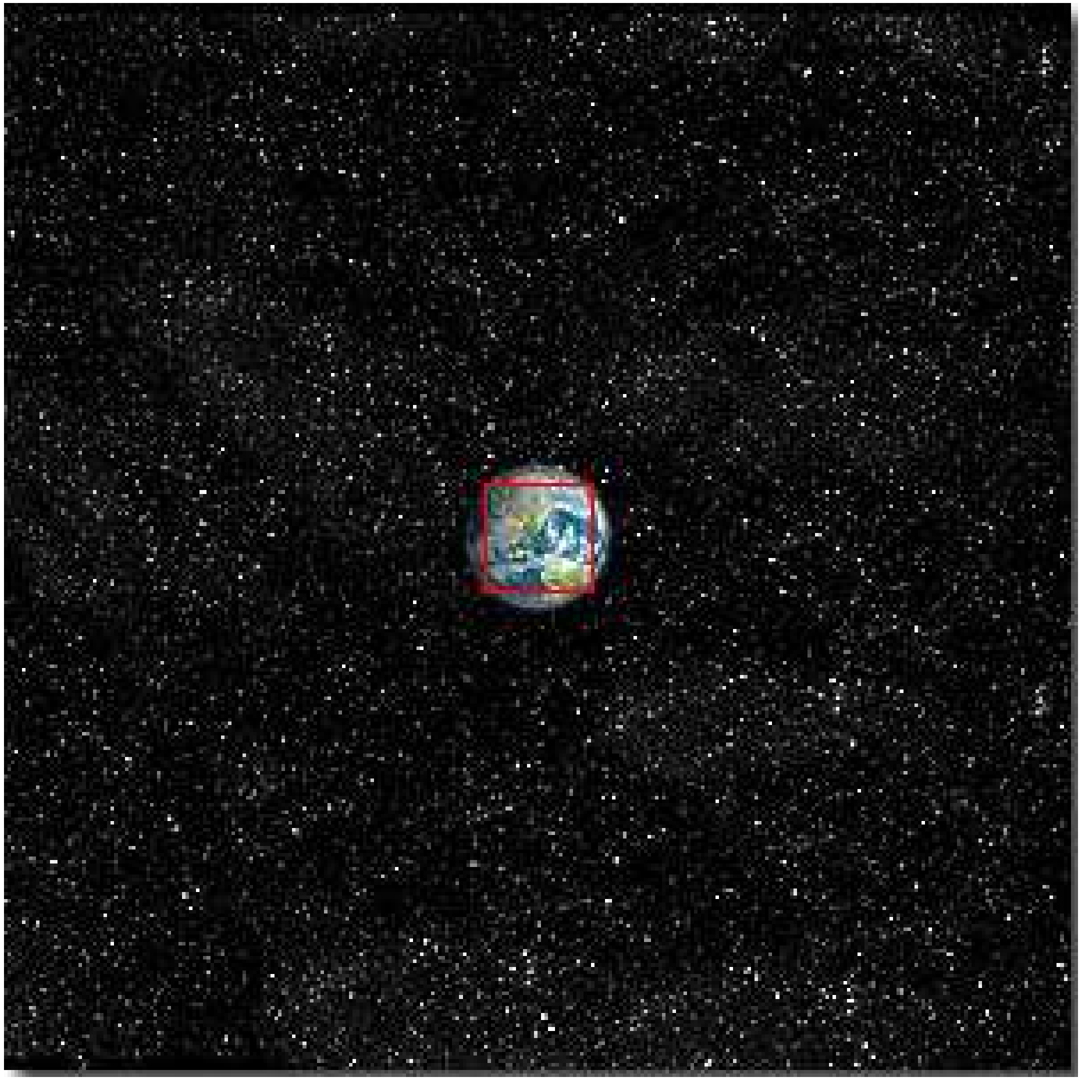
COMO OS MARCIANOS NOS VEÊM?





NOSSO PLANETA TERRA

100.000 quilômetros (10^8m) A Terra ainda pequena.



10.000 quilômetros (10^7m)

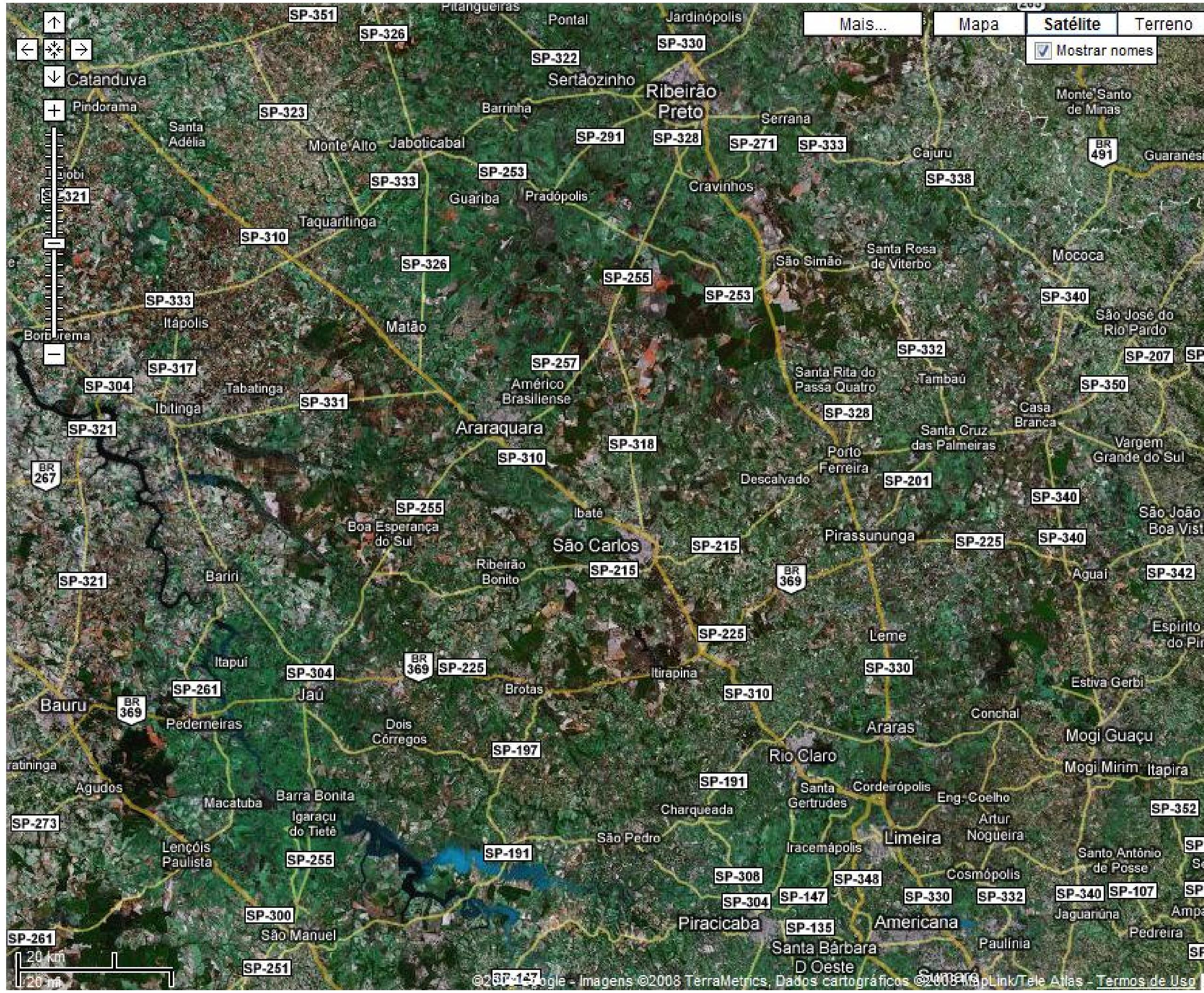
O Hemisfério Norte da Terra.

1.000 Km (10^6m)

Foto característica de satélite (América do Sul)

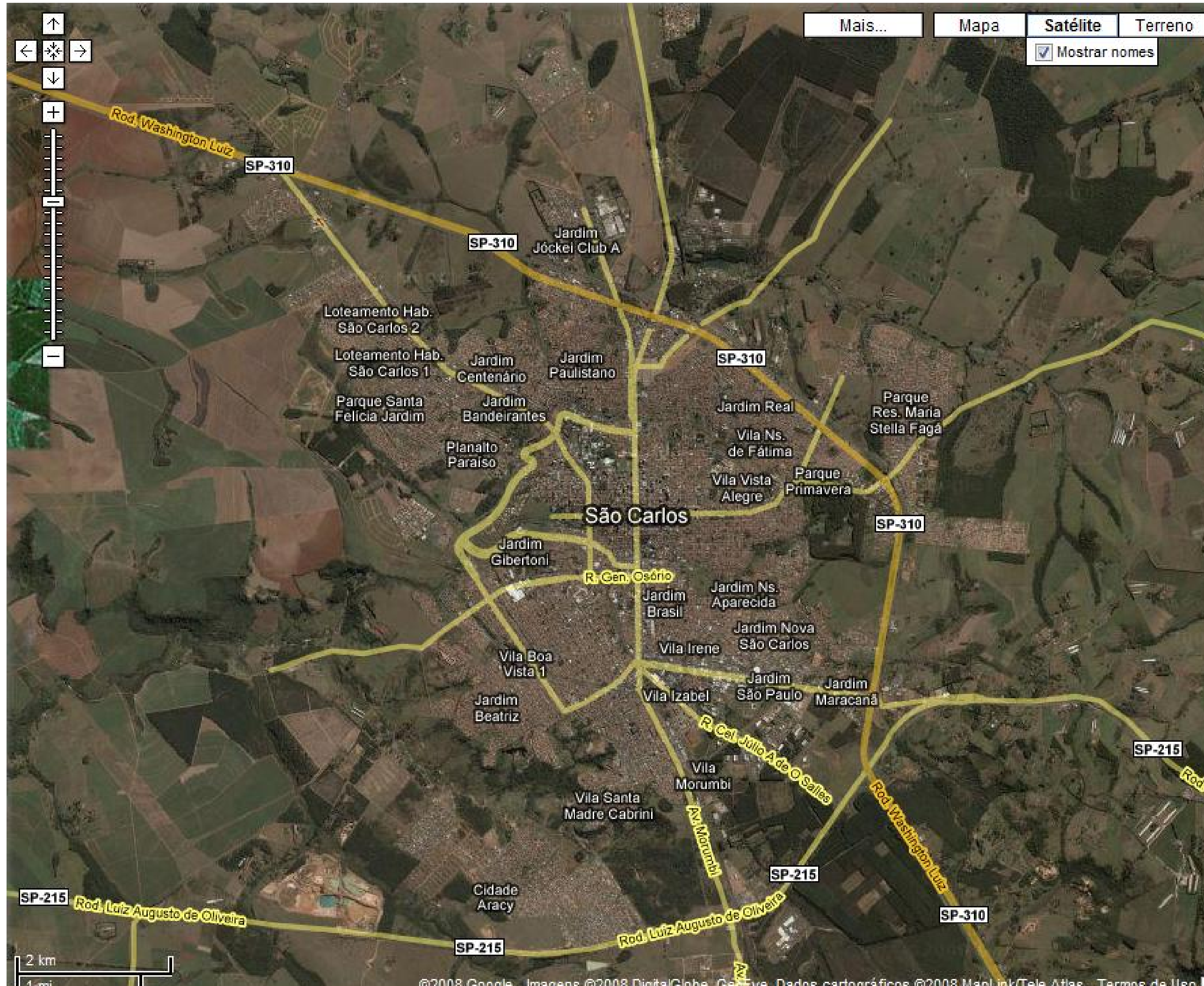
100 Km (10^5m) da superfície.

Cidade de São Carlos, um pouco mais próximo...



100 Km (10^5m)

Os quarteirões mal são vistos.



1000 metros (10^3m)

Vista típica de helicóptero.

Você esta aqui.

10 metros
(10^1m)

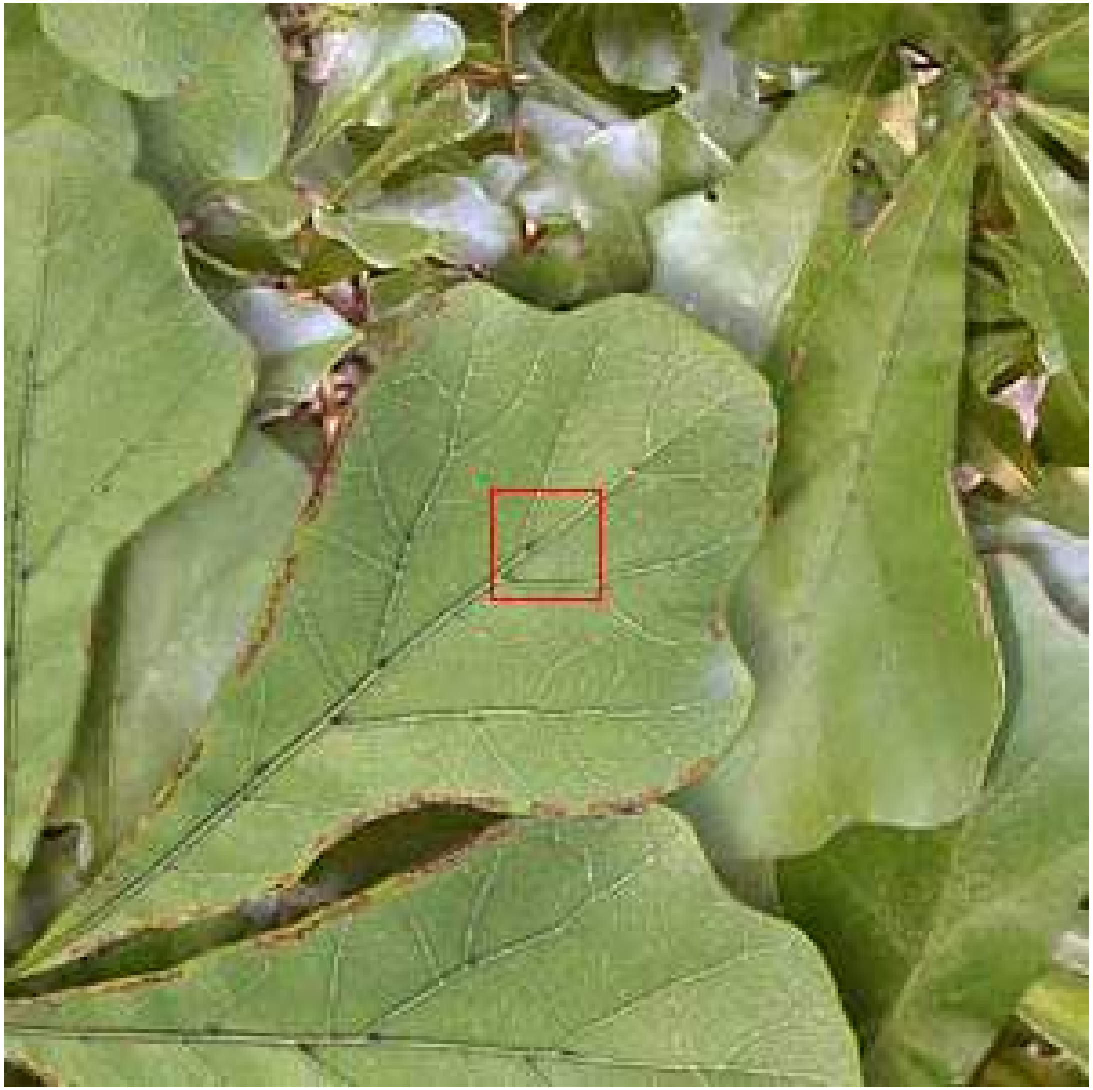
Vista típica de uma janela.

1 metro (10^0m)

Quando olhamos algo com o braço esticado...

10 centímetros (10^{-1}m)

Pode-se tocar nas folhas.



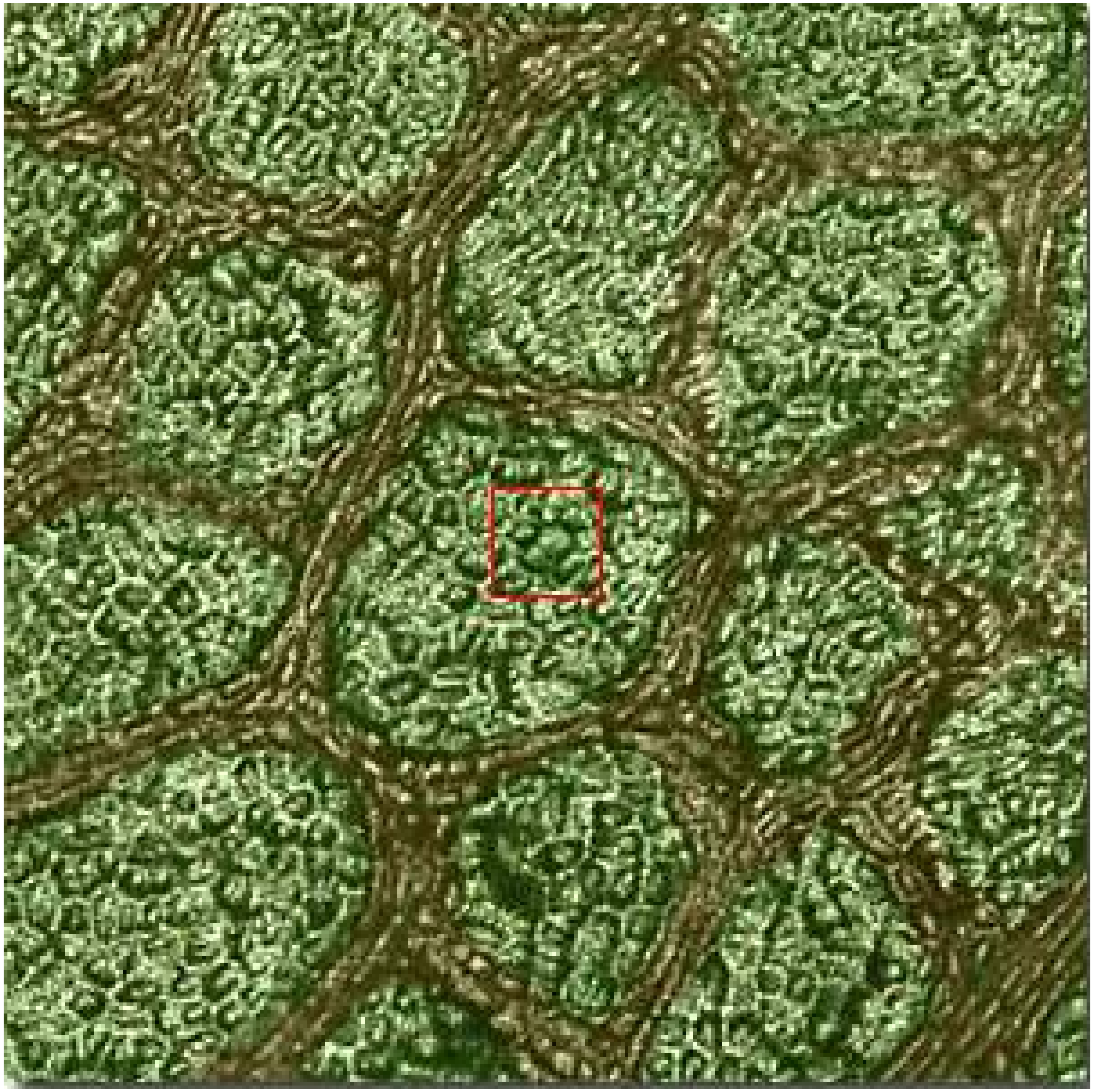
1 centímetro (10^{-2}m)

É possível sentir o cheiro da folha.

1 milímetro (10^{-3}m)

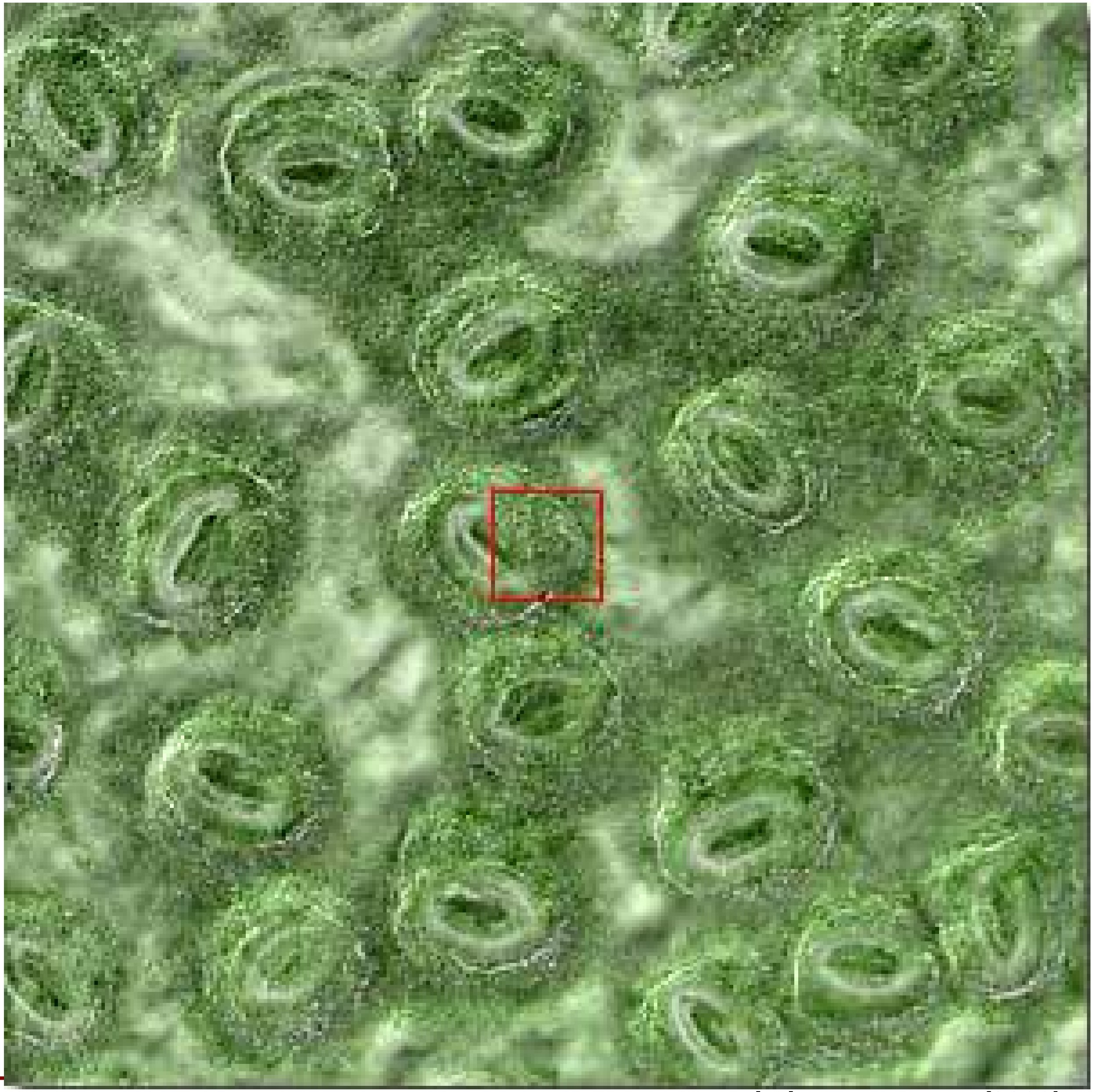
Os vasos da folha aparecem.

100 micra (10^{-4}m) As células praticamente estão definidas.



10 micra (10^{-5}m)

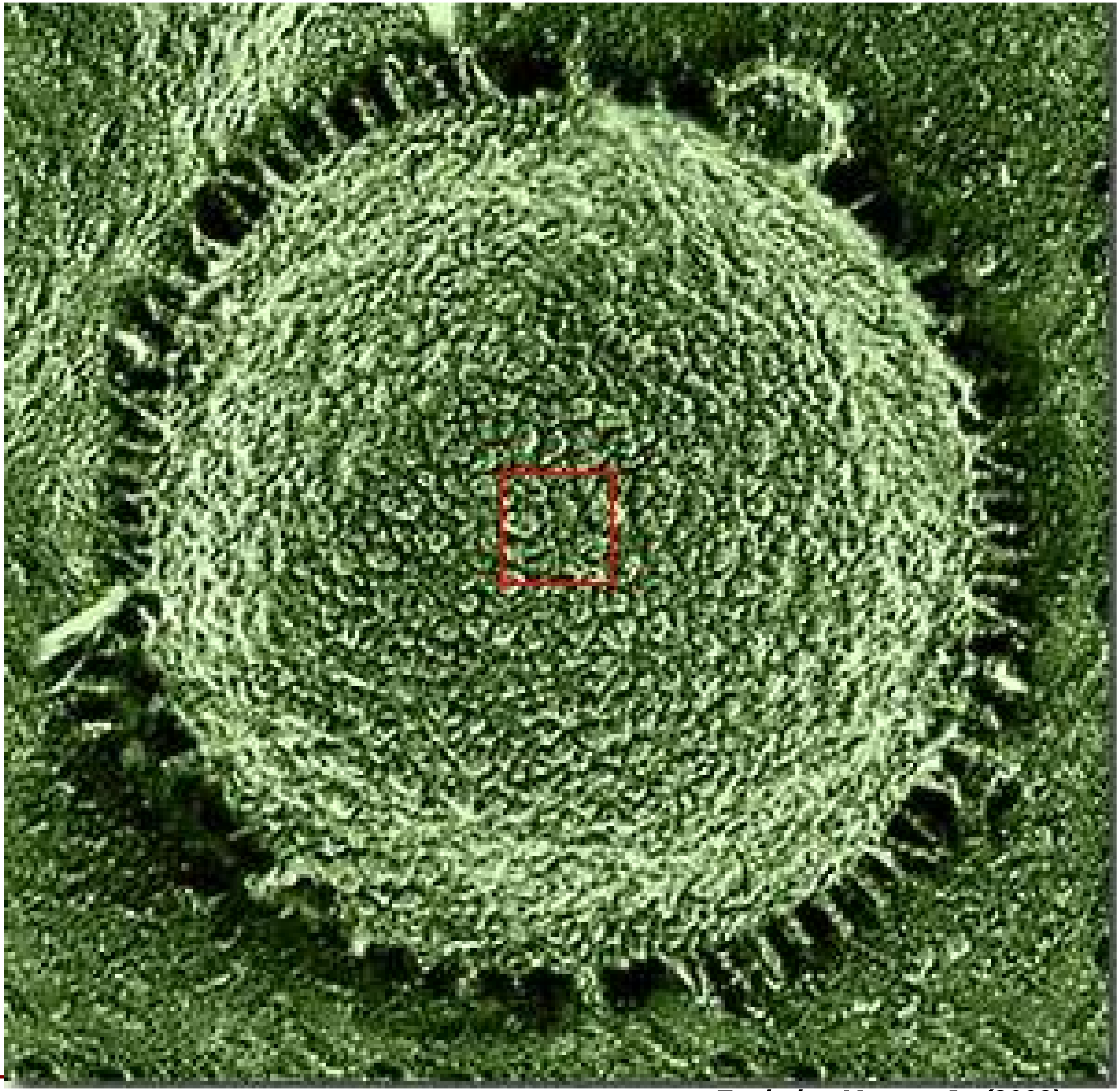
As células aparecem.



Euclydes Marega Jr. (2008)

1 micron (10^{-6}m).

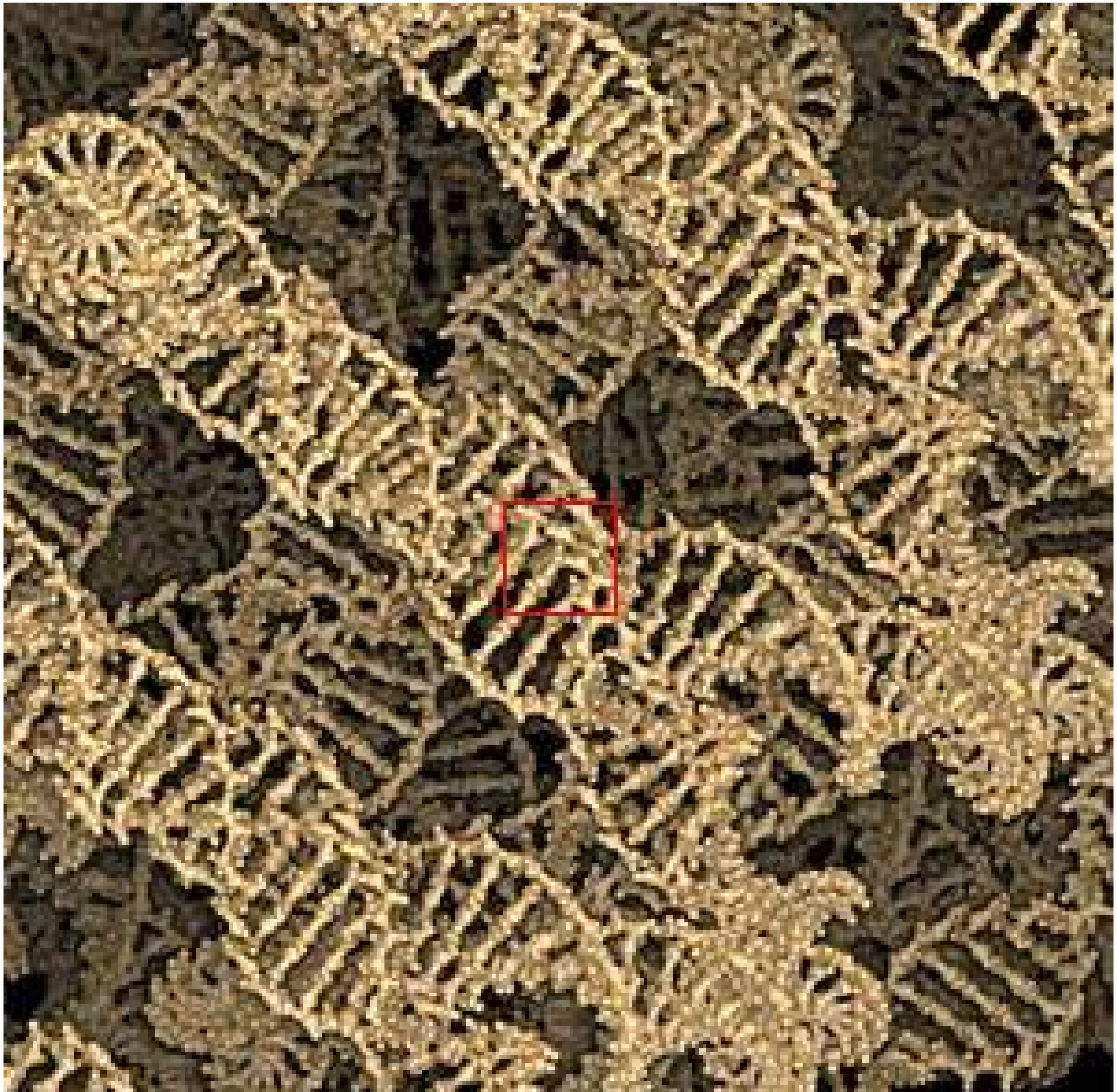
O núcleo da célula já fica visível.



Euclydes Marega Jr. (2008)

1.000 angstrons (10^{-7}m)

Os cromossomas aparecem.



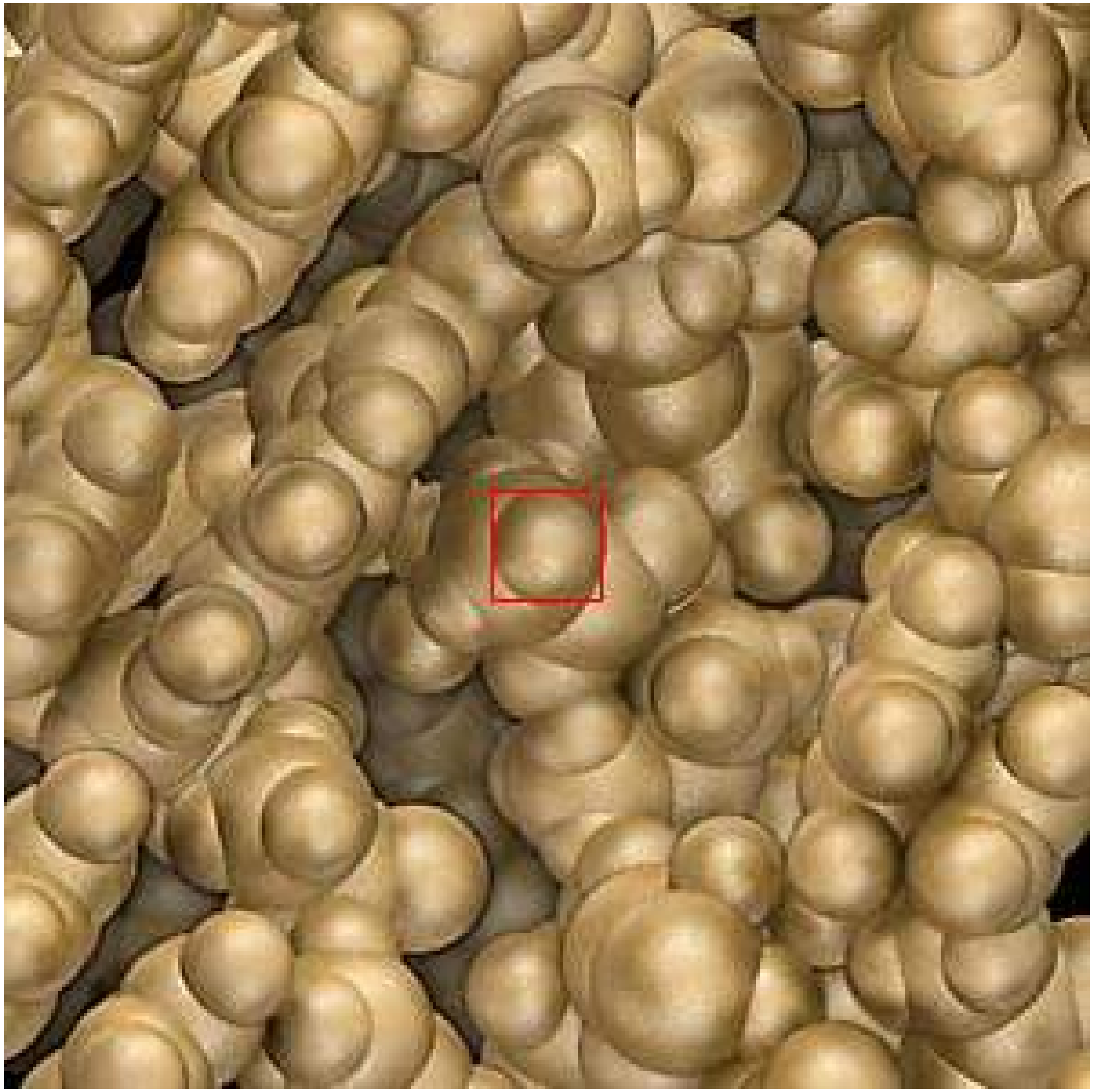
100 angstrons (10^{-8}m)

A cadeia de DNA pode ser visualizada.

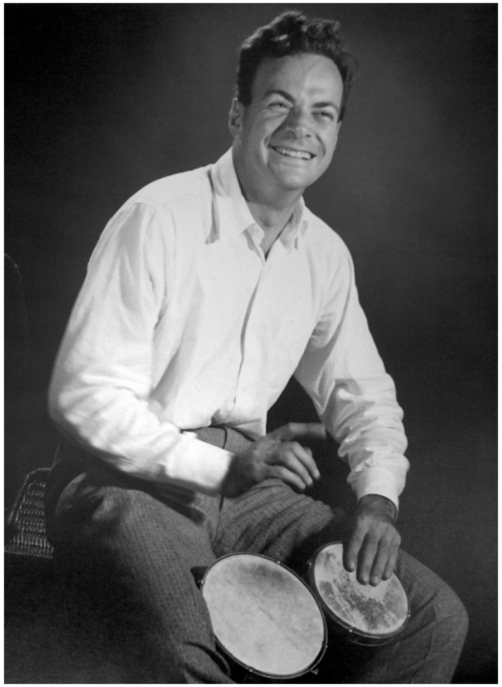
Euclydes Marega Jr. (2008)

1 nanômetro (10^{-9}m)

Os blocos cromossômicos.



QUANDO A NANOTECNOLOGIA TEVE INÍCIO?



Richard P. Feynman –

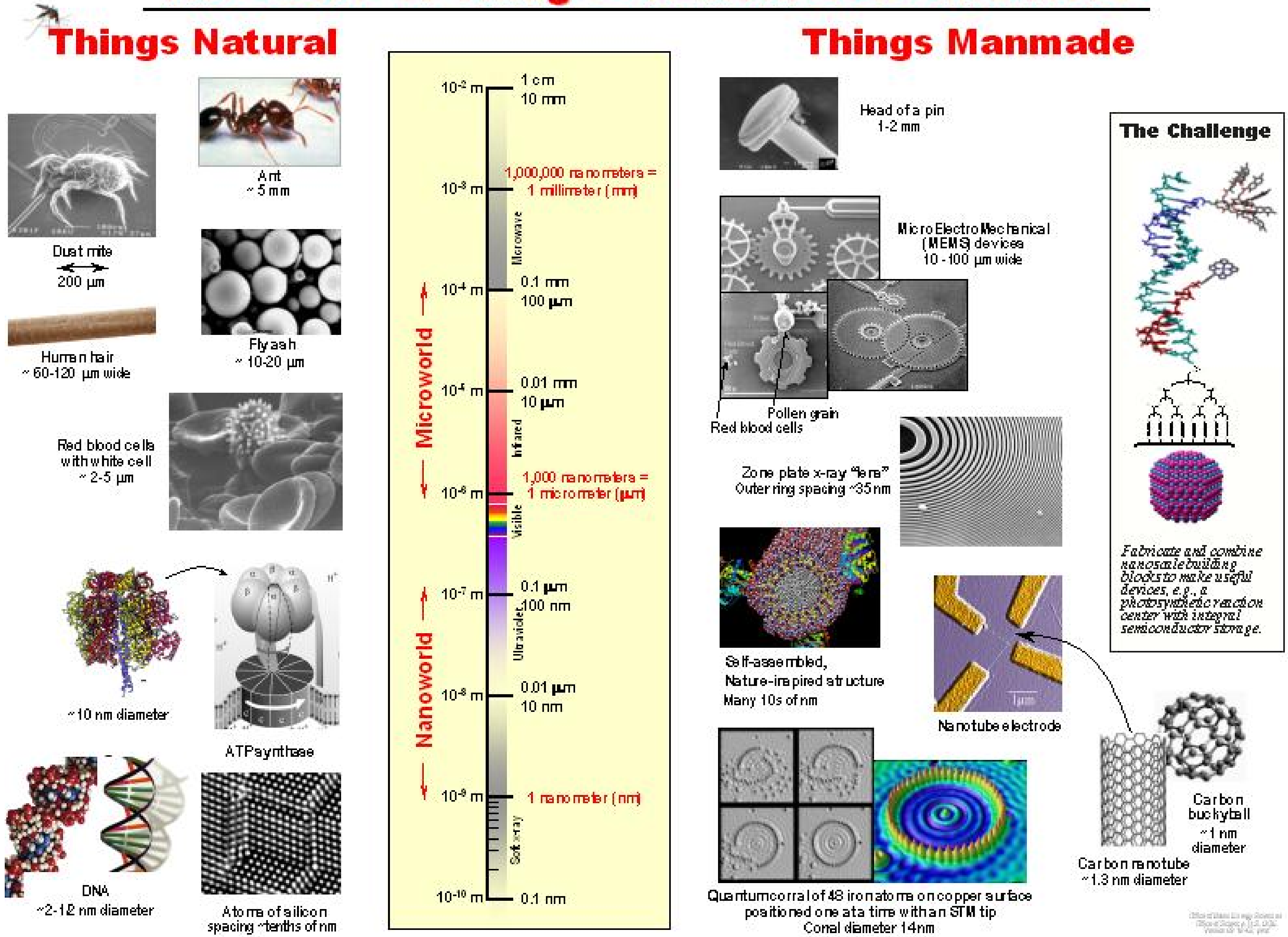
dezembro de1959

"Eu gostaria de descrever um campo, no qual pouco tem sido feito,mas que muita coisa pode ser feito em princípio.Este campo é bastante diferente de outros … ele não fala sobre as leis fundamentais da física…

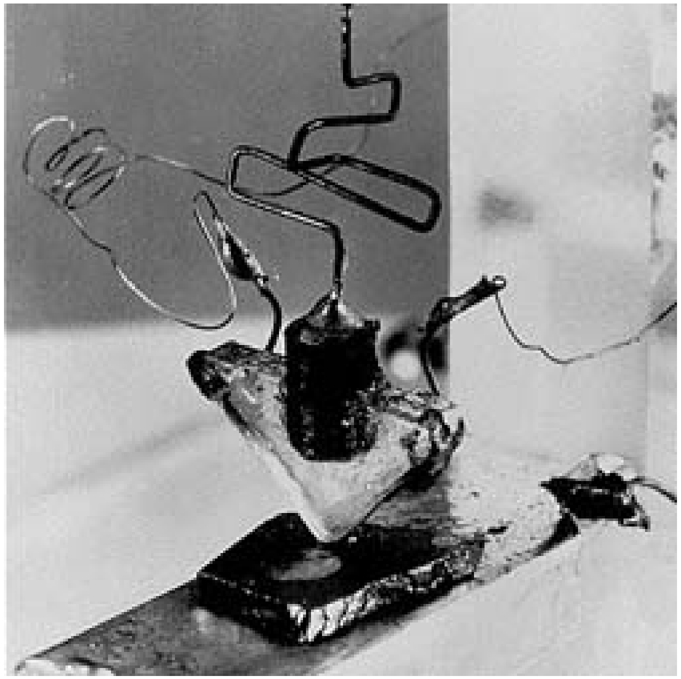
O que desejo falar é o problema de manipular e controlar coisas em escala pequena ."

" Há muito espaço lá em baixo."

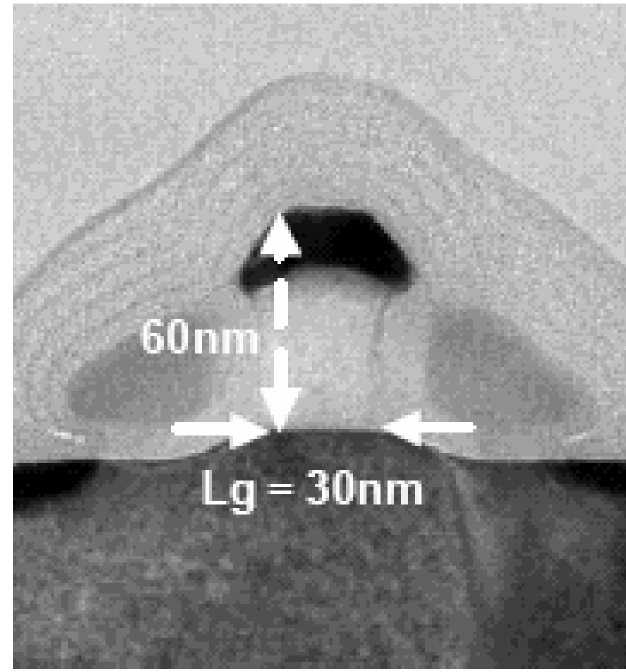
The Scale of Things – Nanometers and More



A re-invenção da eletrônica– O Transistor



?



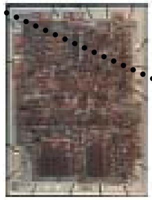
1º Transistor (1947) - Foto

Schockley, Brattain e Bardeen

FET 2005 – Micrografia eletrônica

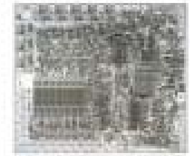
1971

EVOLUÇÃO DOS PROCESSADORES

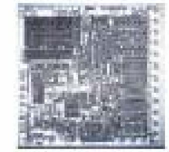


Intel® 4004 processor
Introduced 1971
Initial clock speed
108 KHz
Number of transistors
2,300
Manufacturing technology
10μ

Intel® 8008 processor
Introduced 1972
Initial clock speed
500-800 KHz
Number of transistors
3,500
Manufacturing technology
10μ

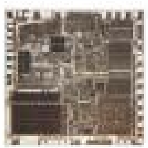


Intel® 8080 processor
Introduced 1974
Initial clock speed
2 MHz
Number of transistors
4,500
Manufacturing technology
6μ

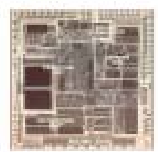


Intel® 8086 processor
Introduced 1978
Initial clock speed
5 MHz
Number of transistors
29,000
Manufacturing technology
3μ

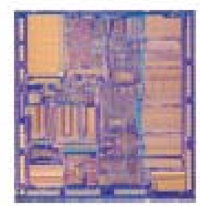
1989



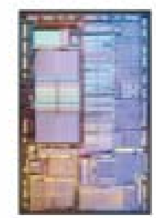
Intel® 8088 processor
Introduced 1979
Initial clock speed
5 MHz
Number of transistors
29,000
Manufacturing technology
3μ



Intel® 286 processor
Introduced 1982
Initial clock speed
6 MHz
Number of transistors
134,000
Manufacturing technology
1.5μ



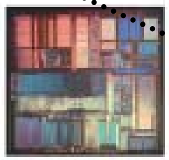
Intel386™ processor
Introduced 1985
Initial clock speed
16 MHz
Number of transistors
275,000
Manufacturing technology
1.5μ



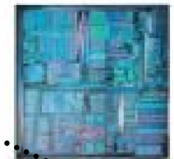
Intel486™ processor
Introduced 1989
Initial clock speed
25 MHz
Number of transistors
1,200,000
Manufacturing technology
1μ

1993

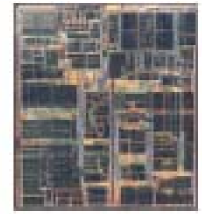
EVOLUÇÃO DOS PROCESSADORES



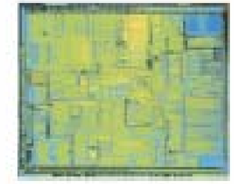
Intel® Pentium® processor
Introduced 1993
Initial clock speed
66 MHz
Number of transistors
3,100,000
Manufacturing technology
0.8µ



Intel® Pentium® Pro processor
Introduced 1995
Initial clock speed
200 MHz
Number of transistors
5,500,000
Manufacturing technology
0.6µ

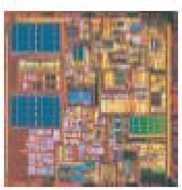


Intel® Pentium® II processor
Intel® Pentium II Xeon® processor
Introduced 1997
Initial clock speed
300 MHz
Number of transistors
7,500,000
Manufacturing technology
0.25µ

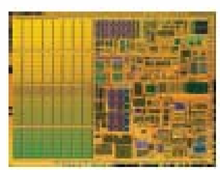


Intel® Pentium® III processor
Intel® Pentium® III Xeon® processor
Introduced 1999
Initial clock speed
500 MHz
Number of transistors
9,500,000
Manufacturing technology
0.18µ

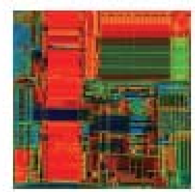
2005



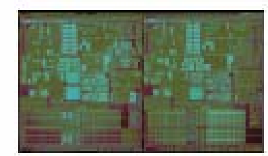
Intel® Pentium® 4 processor
Introduced 2000
Intel® Xeon® processor
Introduced 2001
Initial clock speed
1.5 GHz
Number of transistors
42,000,000
Manufacturing technology
0.18µ



Intel® Pentium® M processor
Introduced - 2002
Initial Clock Speed
1.7 GHz
Number of transistors
55,000,000
Manufacturing technology
90nm



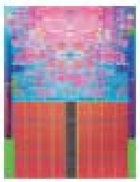
Intel® Itanium® 2 processor
Introduced 2002
Initial clock speed
1 GHz
Number of transistors
220,000,000
Manufacturing technology
0.13µ



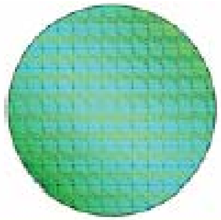
Intel® Pentium® D processor
Introduced 2005
Initial clock speed
3.2 GHz
Number of transistors
291,000,000
Manufacturing technology
65nm

EVOLUÇÃO DOS PROCESSADORES

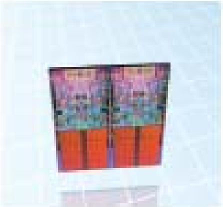
2006 ··► 2007



Intel® Core™ 2 Duo processor
Intel® Core™2 Extreme processor
Dual-Core Intel® Xeon® processor
Introduced 2006
Initial clock speed
2.93 GHz
Number of transistors
291,000,000
Manufacturing technology
65nm

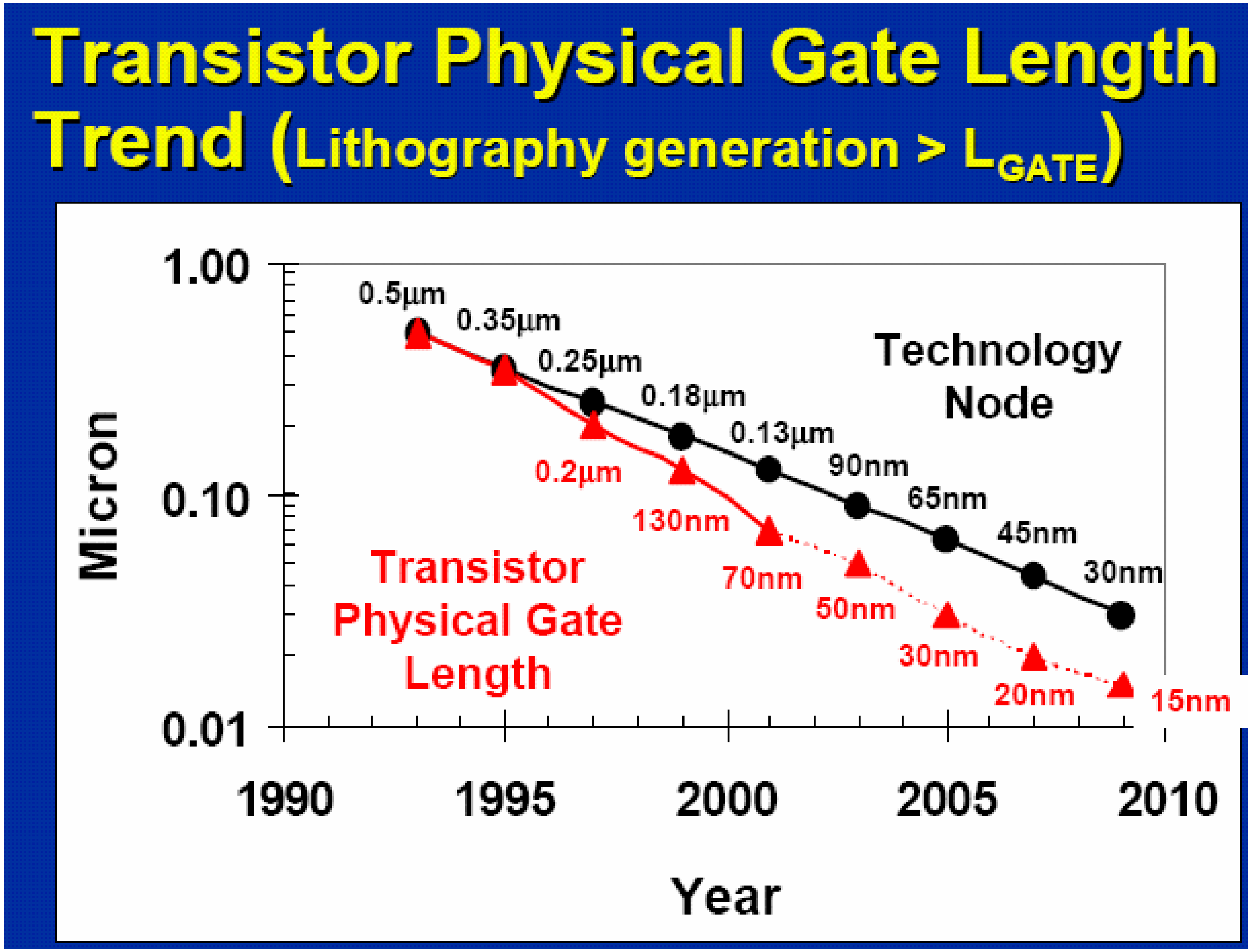


Dual-Core Intel® Itanium® 2 processor 9000 series
Introduced 2006
Initial clock speed
1.66 GHz
Number of transistors
1,720,000,000
Manufacturing technology
90nm



Quad-Core Intel® Xeon® processor
Quad-Core Intel® Core™2 Extreme processor
Introduced 2006
Intel® Core™2 Quad processors
Introduced 2007
Initial clock speed
2.66 GHz
Number of transistors
582,000,000
Manufacturing technology
65nm

Quad-Core Intel® Xeon® processor (Penryn)
Dual-Core Intel® Xeon® processor (Penryn)
Quad-Core Intel® Core™2 Extreme processor (Penryn)
Introduced 2007
Initial clock speed
> 3 GHz
Number of transistors
820,000,000
Manufacturing technology
45nm

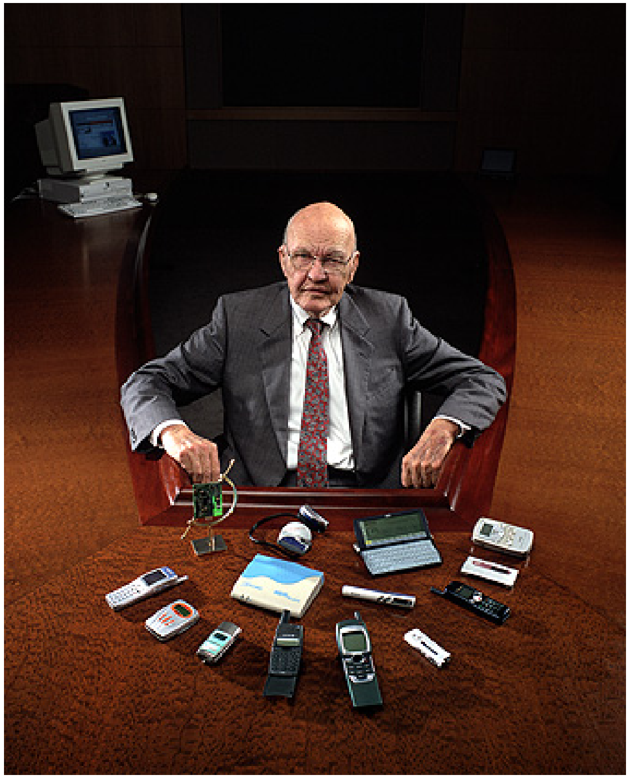


Source: Intel – www.intel.com

Robert Chau

A integração na eletrônica

Jack Kilby (1958) – *nobel 2000*

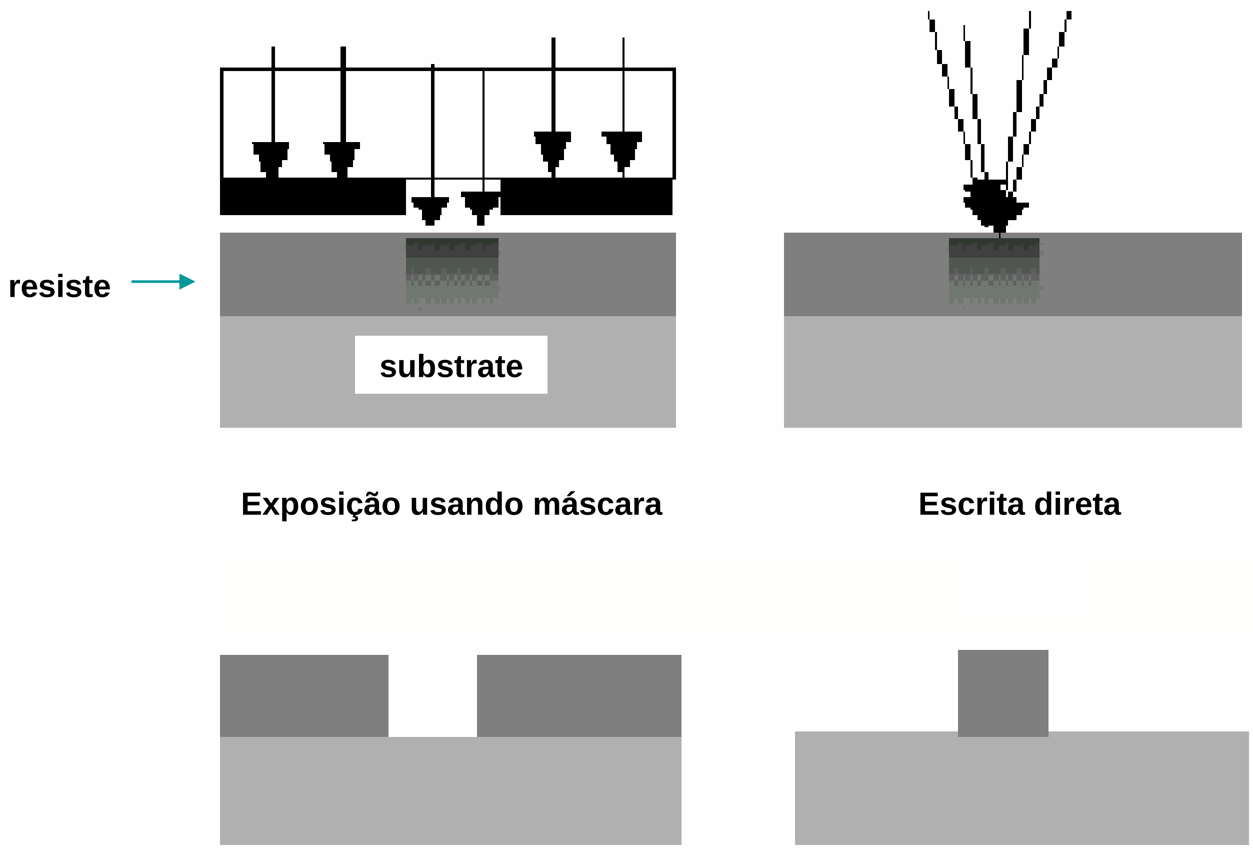


COMO FABRICAR EM NANOESCALA

► Litografia (Escrita)
- Técnicas Litográficas
- Nova Geração de Técnicas

► Auto-organização

LITOGRAFIA



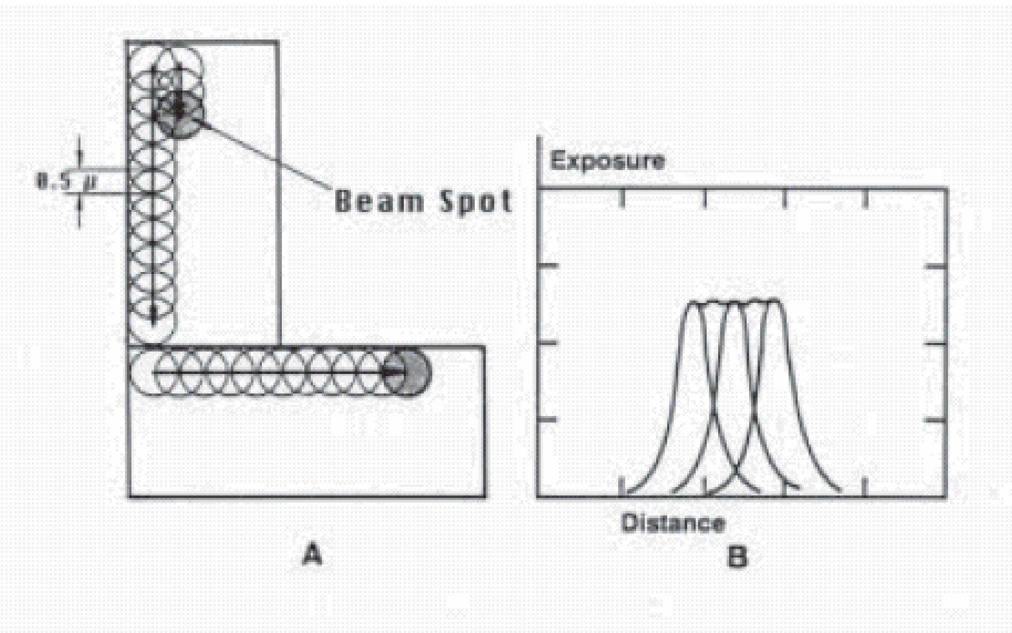
Exposição usando máscara

Escrita direta

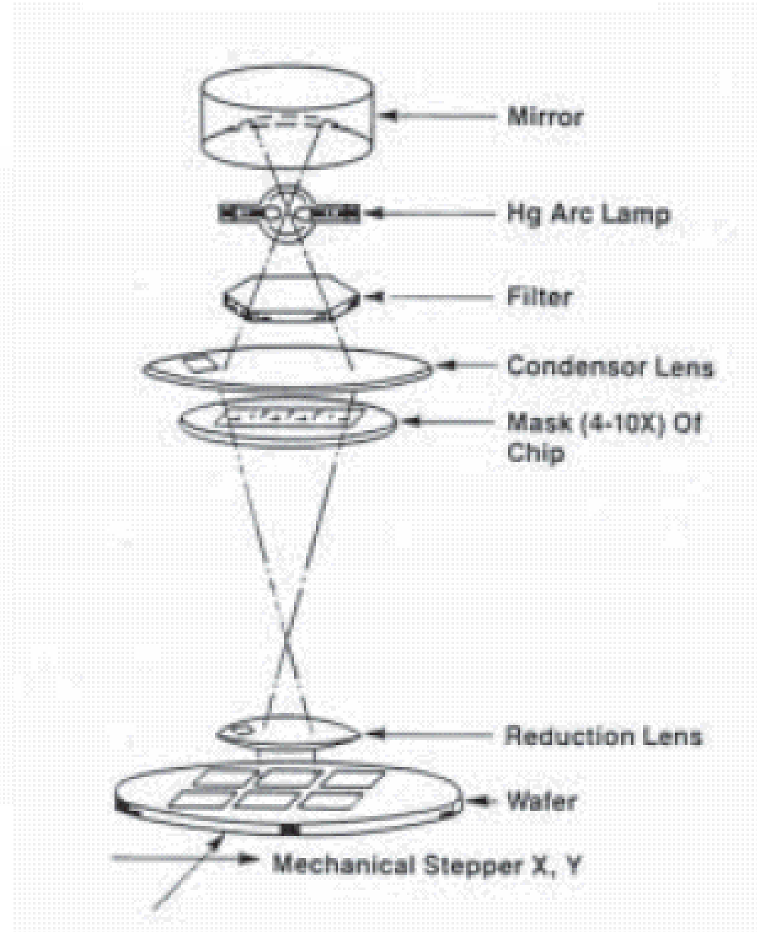
Resiste positivo

Resiste negativo

ESCRITA DIRETA



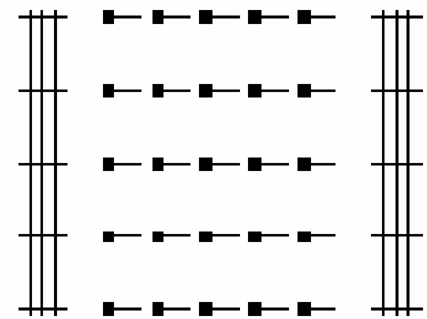
EXPOSIÇÃO COM MÁSCARA



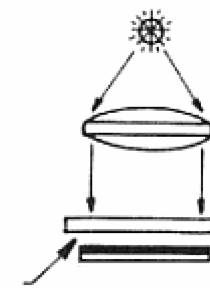
Source: W. Moreau – Semiconductor Lithography

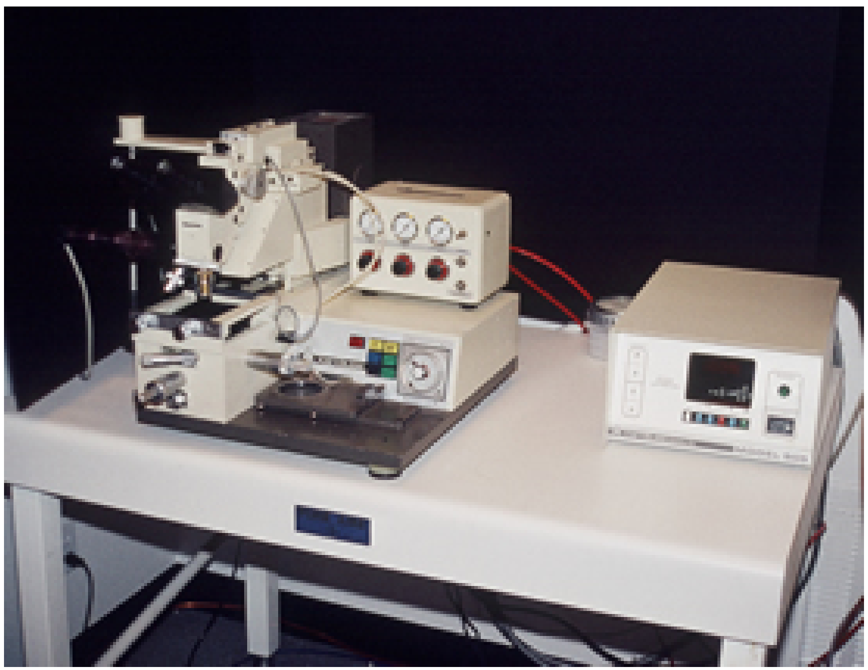
LITOGRAFIA ÓPTICA CONVENCIONAL

MÁSCARA → **LUZ(radiação)** → **PADRÃO**



MÁSCARA(padrão)





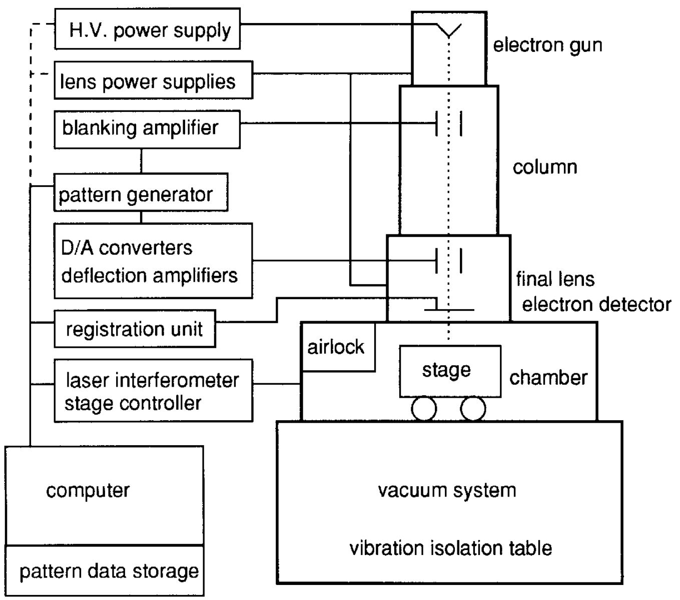
Fotoalinhadora

Deposição do resiste

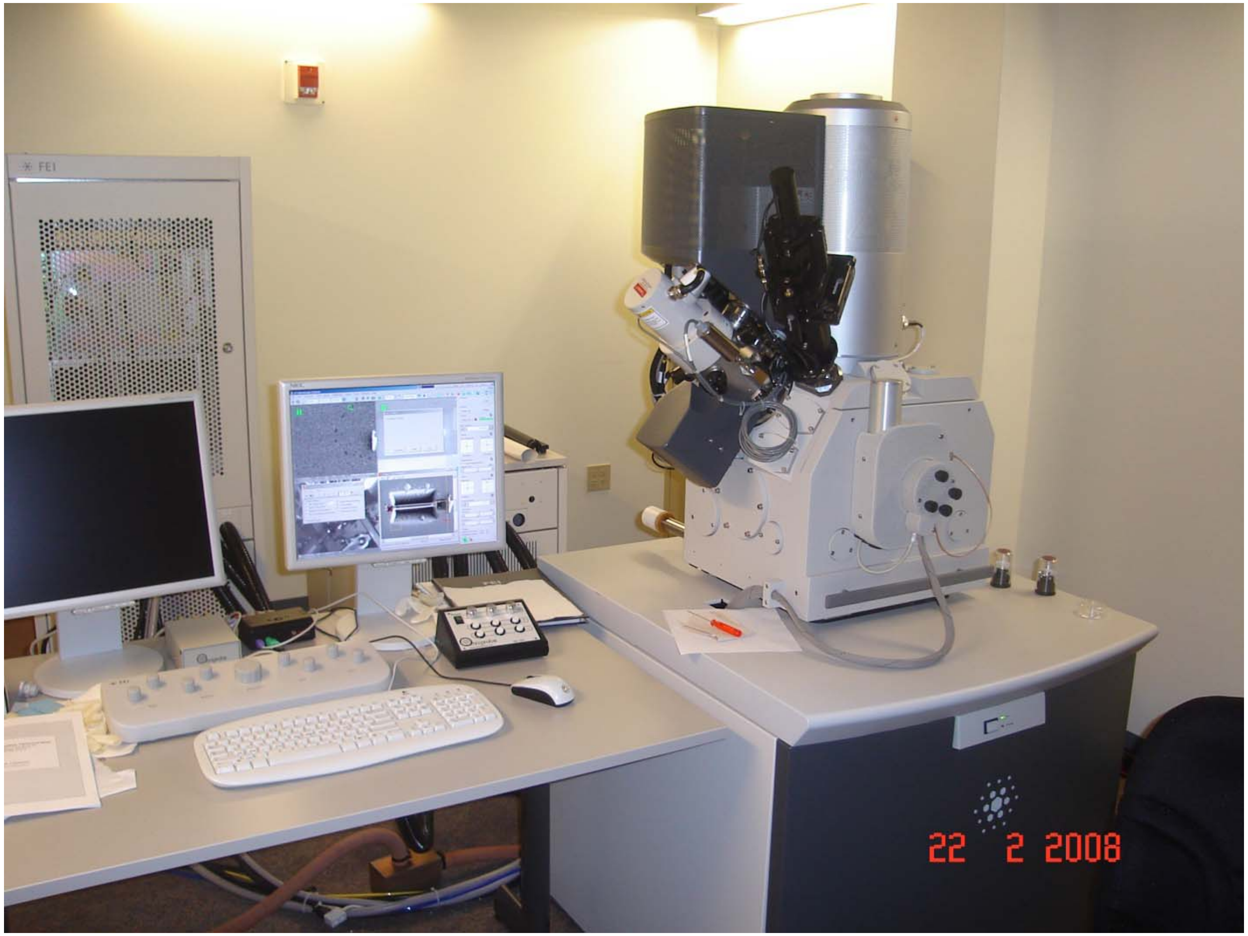
LITOGRAFIA COM FEIXE DE ELÉTRONS

PADRÕES → **FEIXE DE ELÉTRONS** → **ESCRITA DIRETA**

Source: Raith Nanolithography

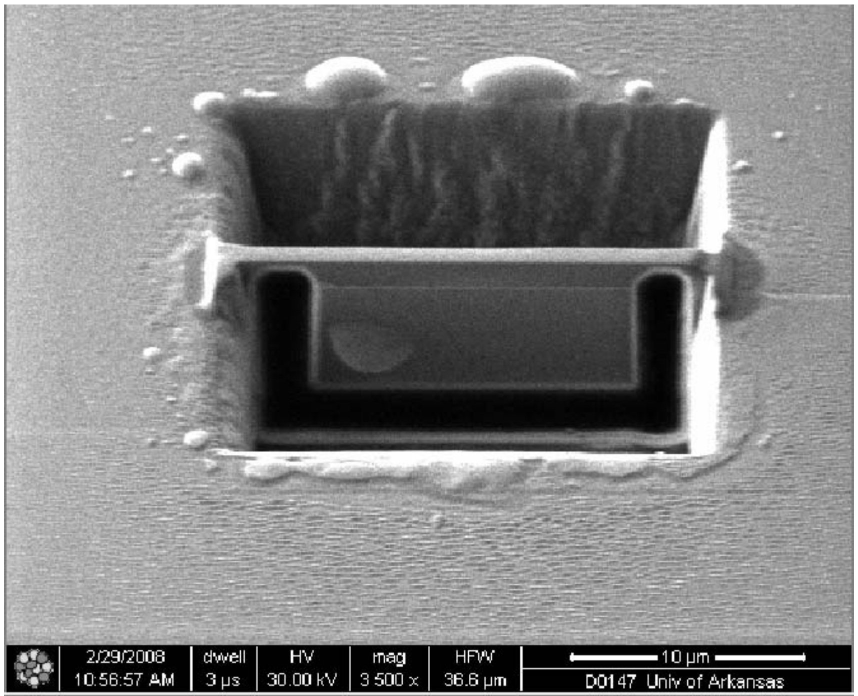


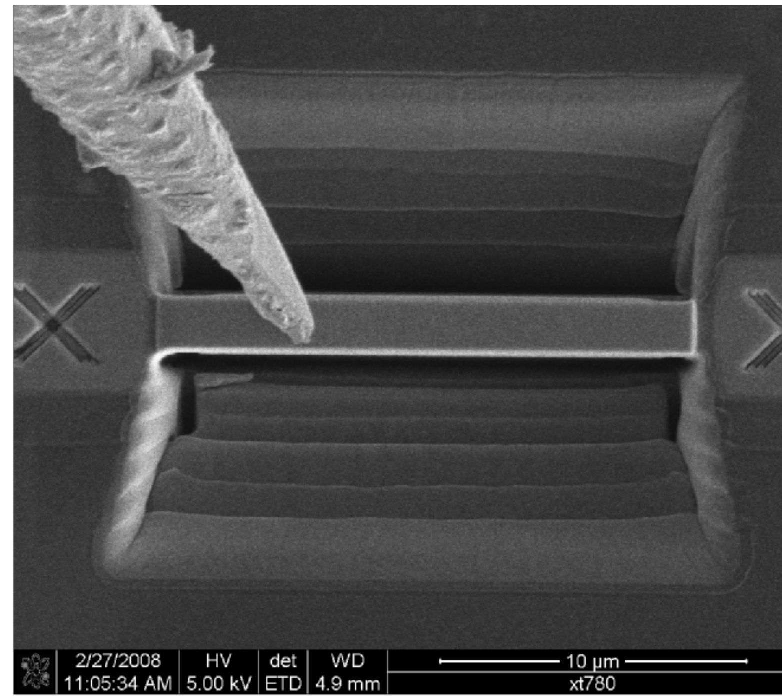
LITOGRAFIA COM FEIXE DE IONS –
Escrita Direta



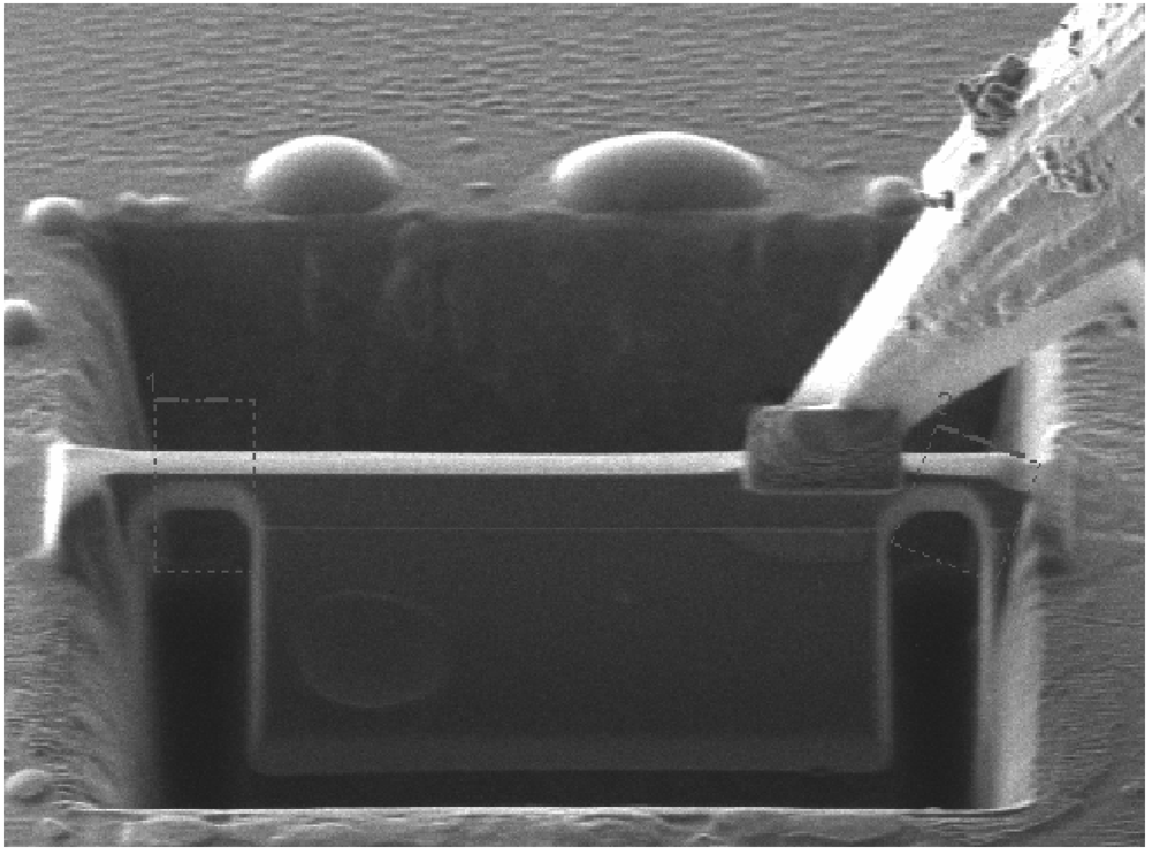
FIB – FOCUS ION BEAM

LITOGRAFIA COM FEIXE DE IONS

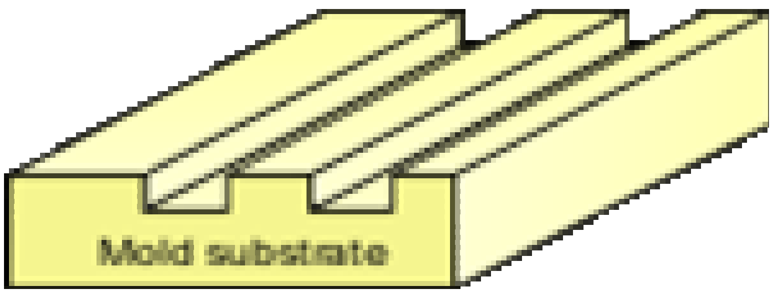


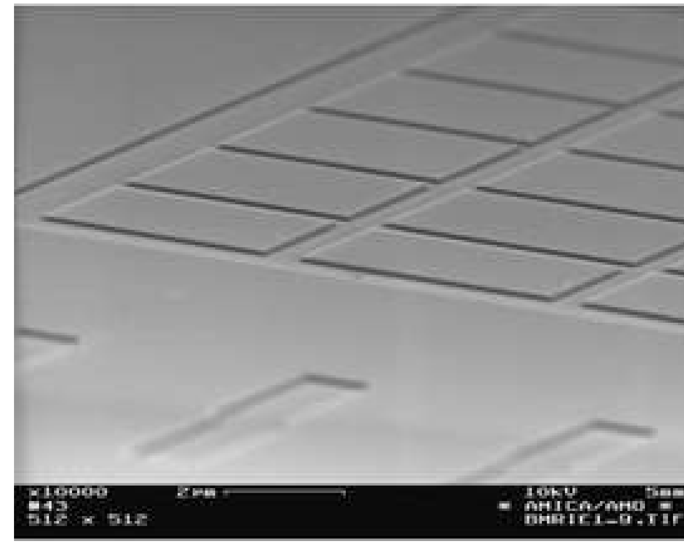


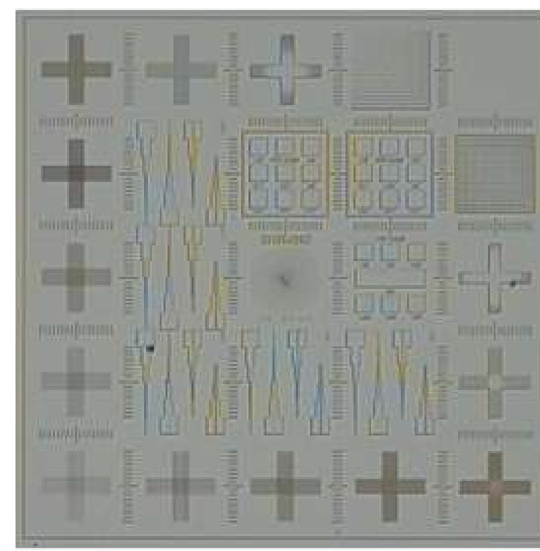
LITOGRAFIA COM FEIXE DE IONS



IMPRESSÃO EM NANOESCALA



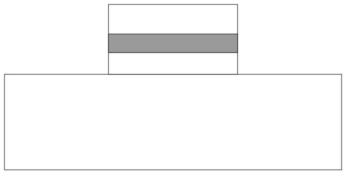




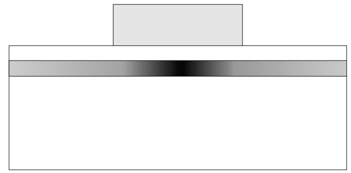
Auto-organização

Técnicas para fabricação de Nanoestruturas Semicondutoras

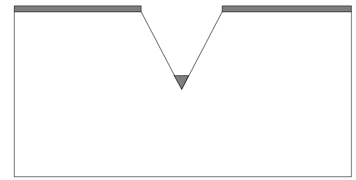
Técnicas Litográficas



Restrição de tamanho física



Potencial Eletrostático



Crescimento seletivo

- Processamento requer ataque químico
- Processamento com muitas etapas
- Resolução da 'escrita' litográfica

Auto-organização

Precipitação em vidros

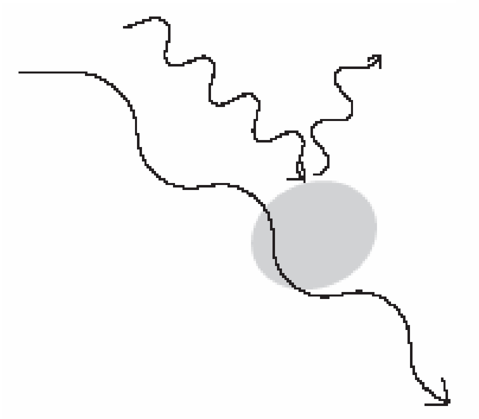
Nucleação durante tratamento térmico de vidros dopados com Semicondutores II-VI

Auto-organização durante o crescimento epitaxial

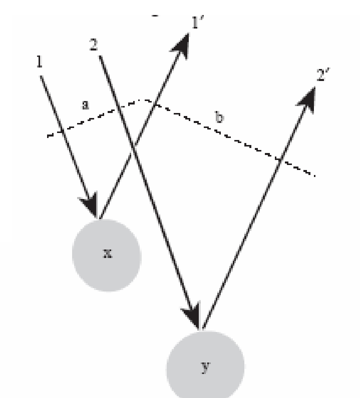
$\Rightarrow$ **Pontos Quânticos Naturais (III/V, IV, II/VI e IV/VI)**

Auto-organização na Natureza e as cores

Incoerente

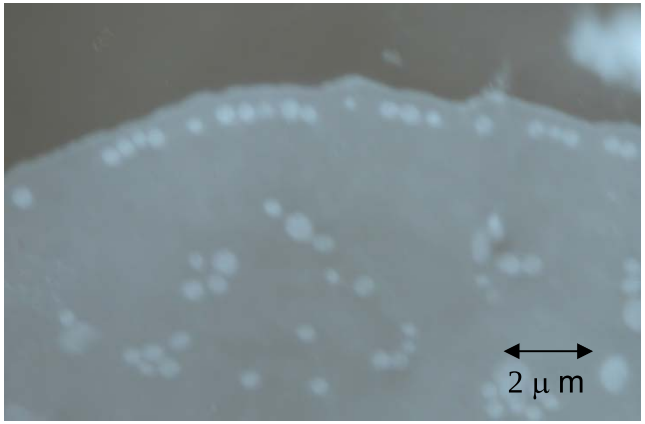


coerente

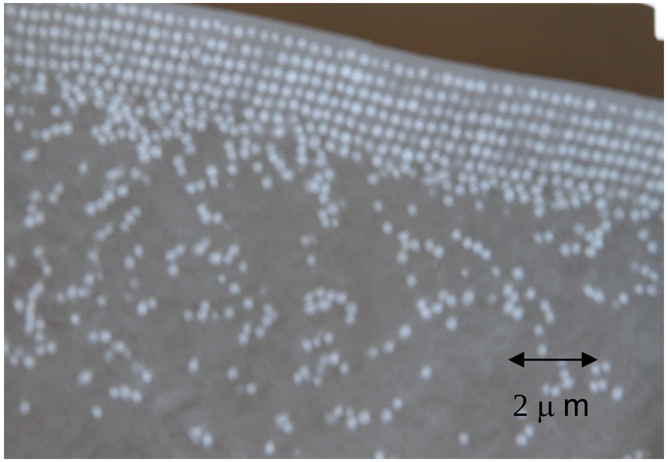


Imagens obtidas por Microscopia Eletrônica de Transmissão de penas de Pavão

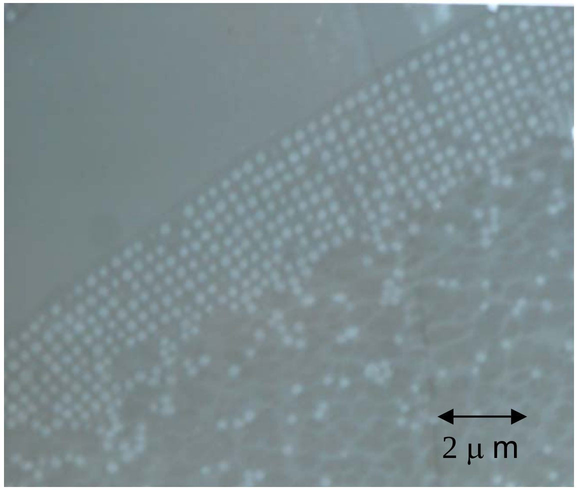
Idade=1 ano



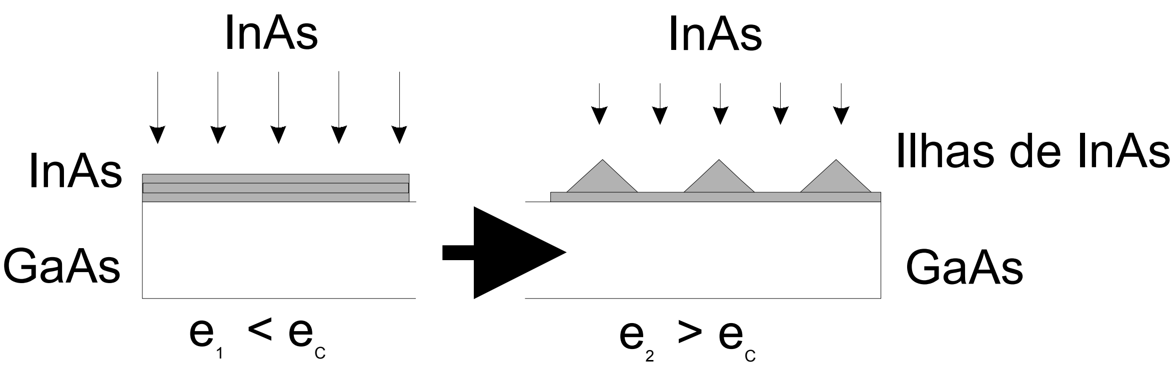
Idade=3 anos

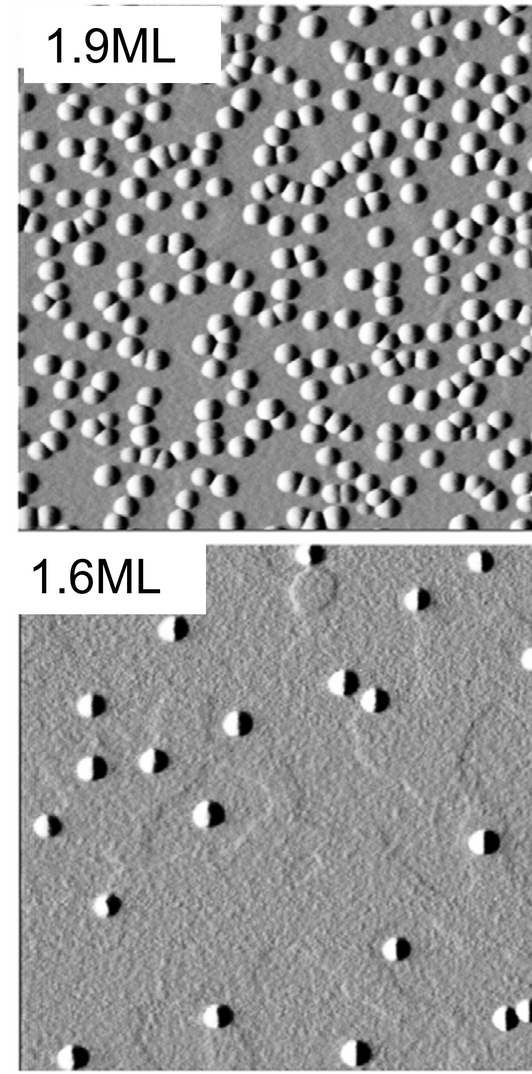


Idade=6 anos



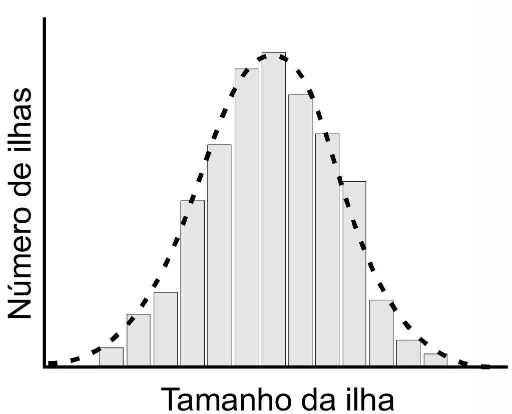
Pontos Quânticos Naturais – Átomos Artificiais

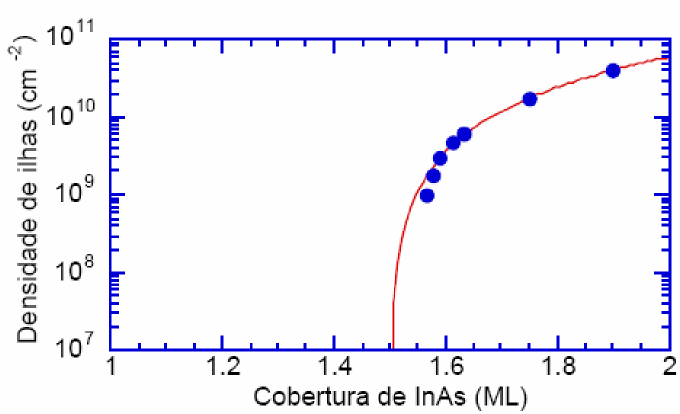


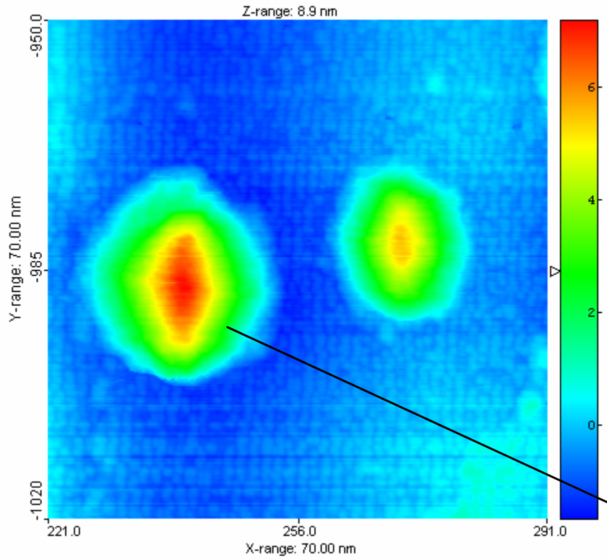


1µm x 1µm - AFM

- Forma piramidal com base ~20 nm e altura ~10 nm
- Densidade ~10^{10} cm-^{2}
- Ausência de deslocações
- Distribuição de tamanhos

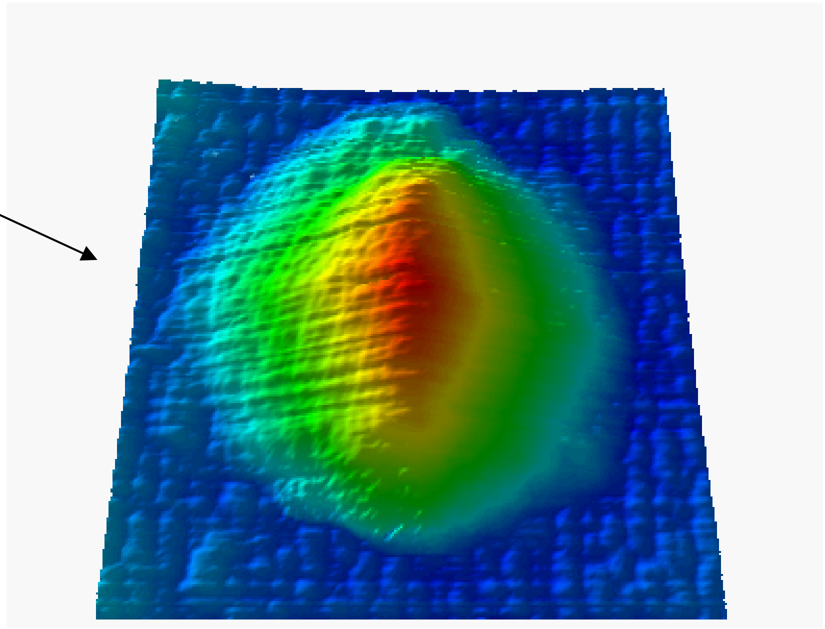




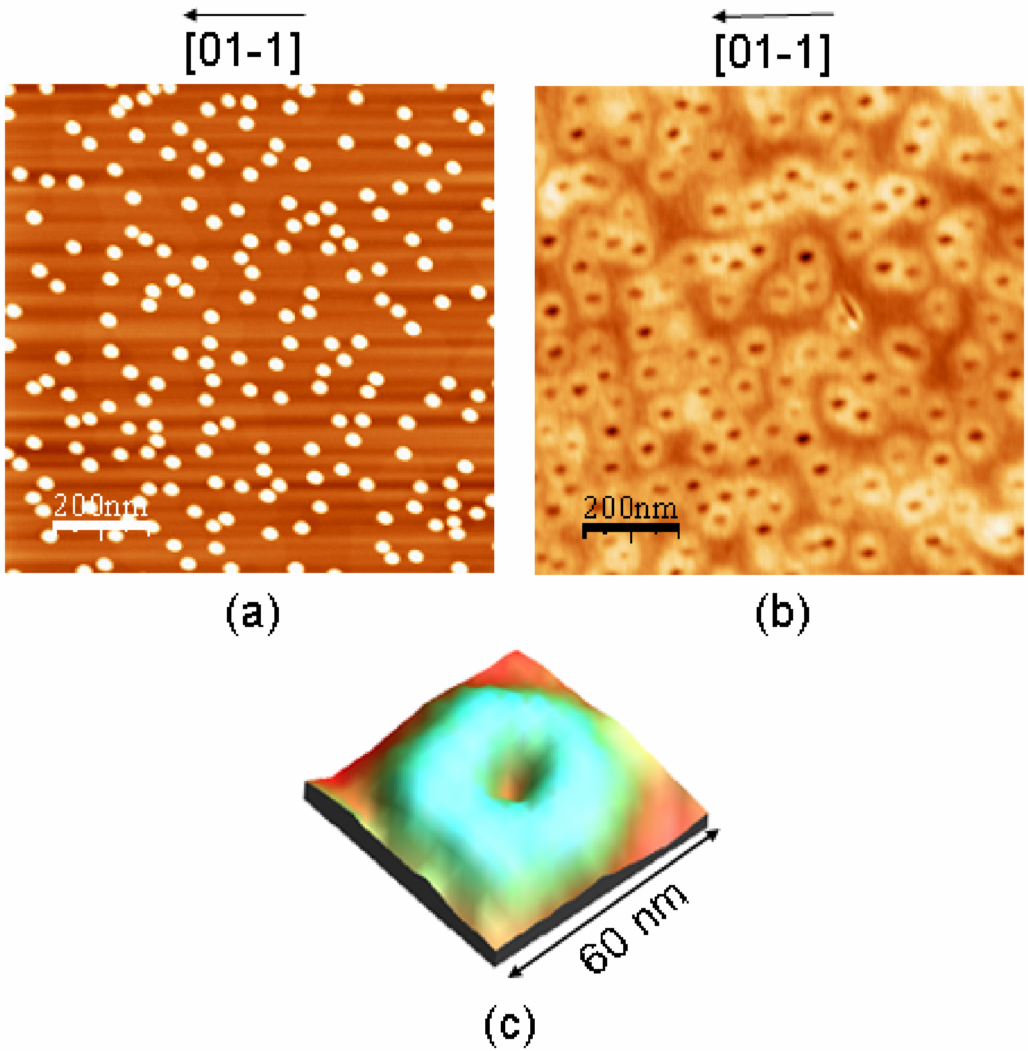


Pontos de InAs/GaAs(100)

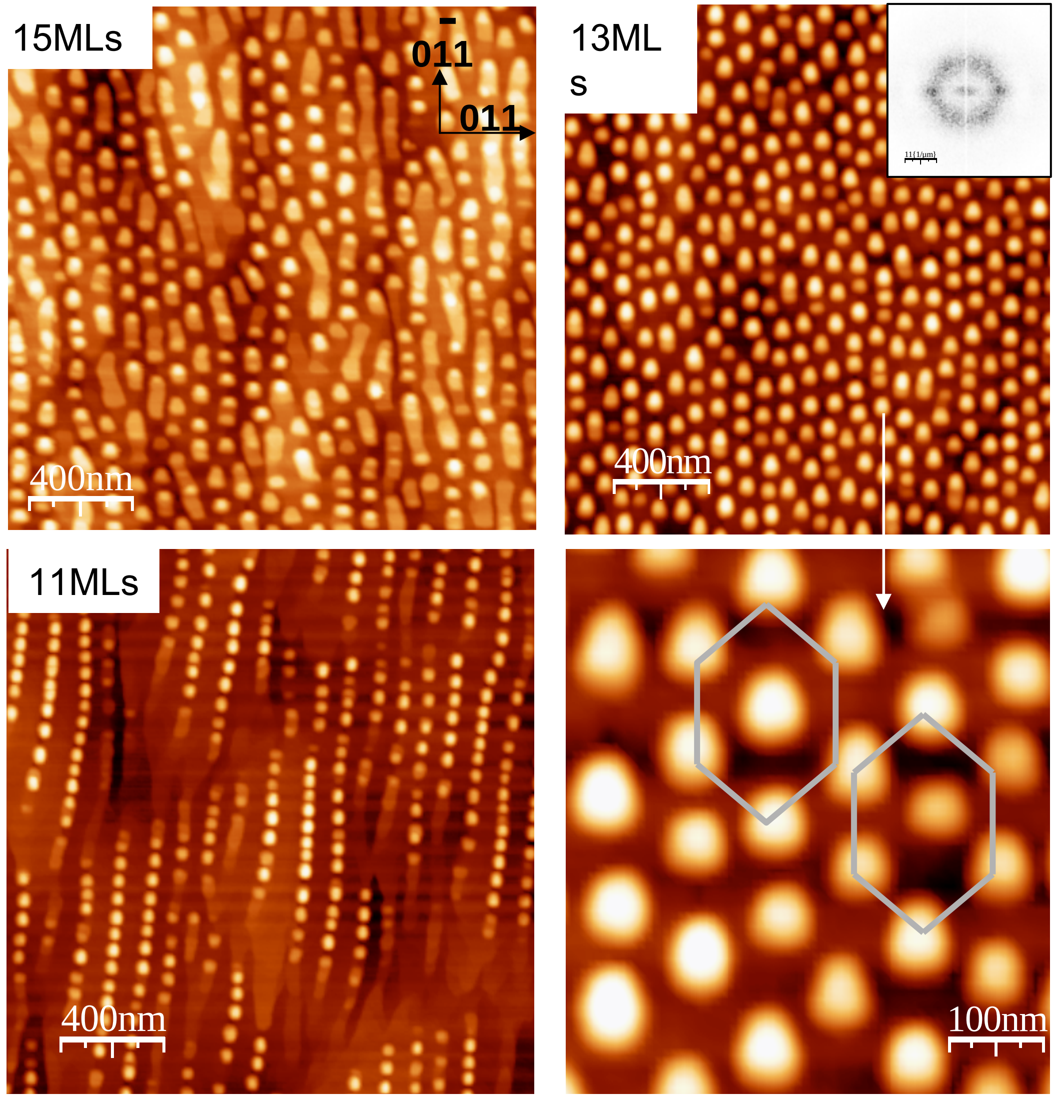
STM – Microscopia de Tunelamento em Ultra-alto vácuo



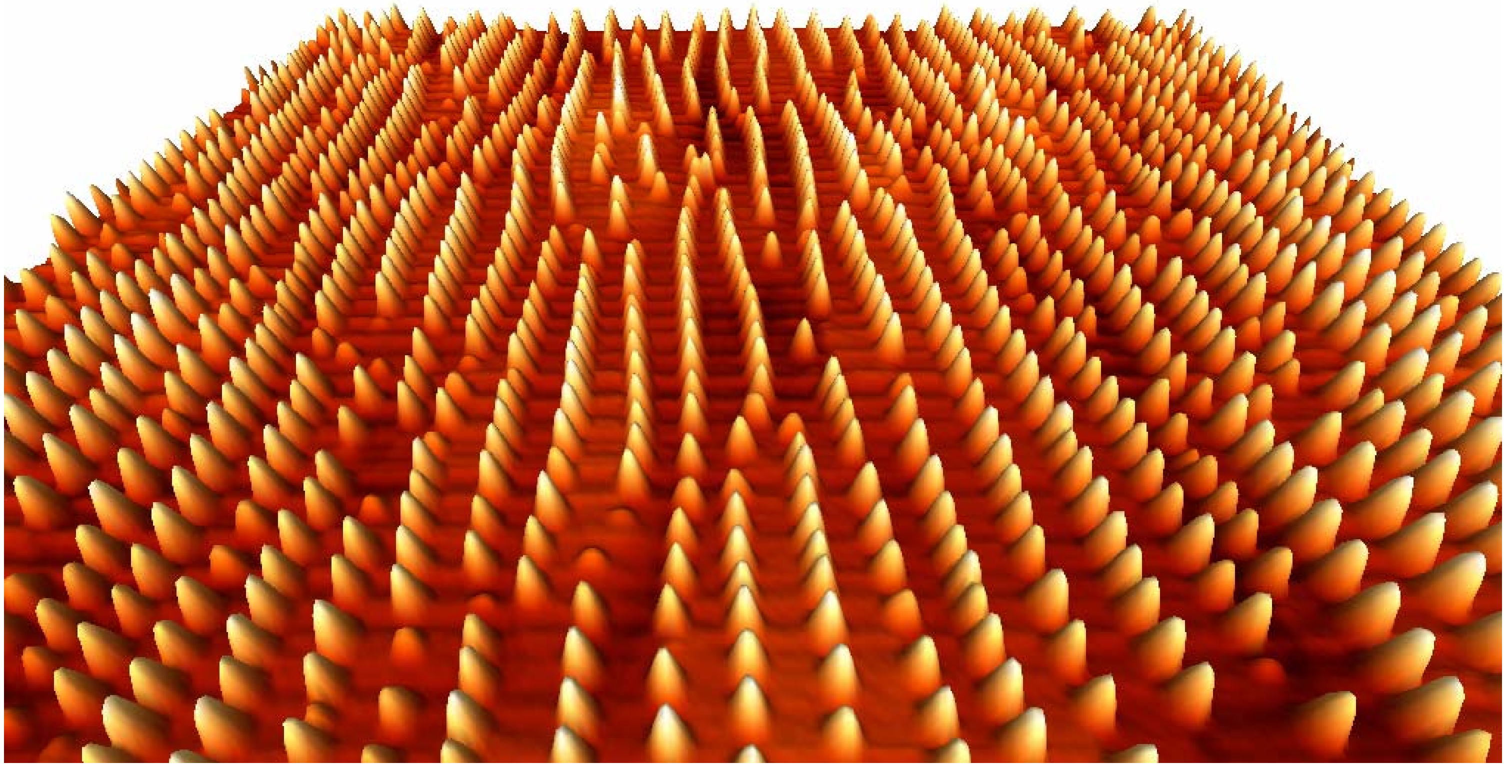
Anéis Quânticos – Quantum Rings



Rede Hexagonal em multicamadas Pontos Quânticos de $In_{0.30}Ga_{0.7}As$

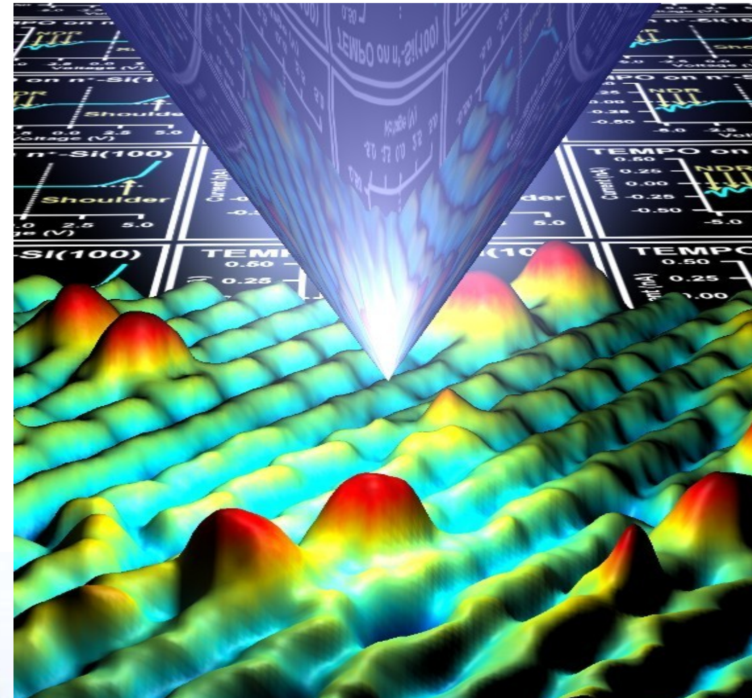


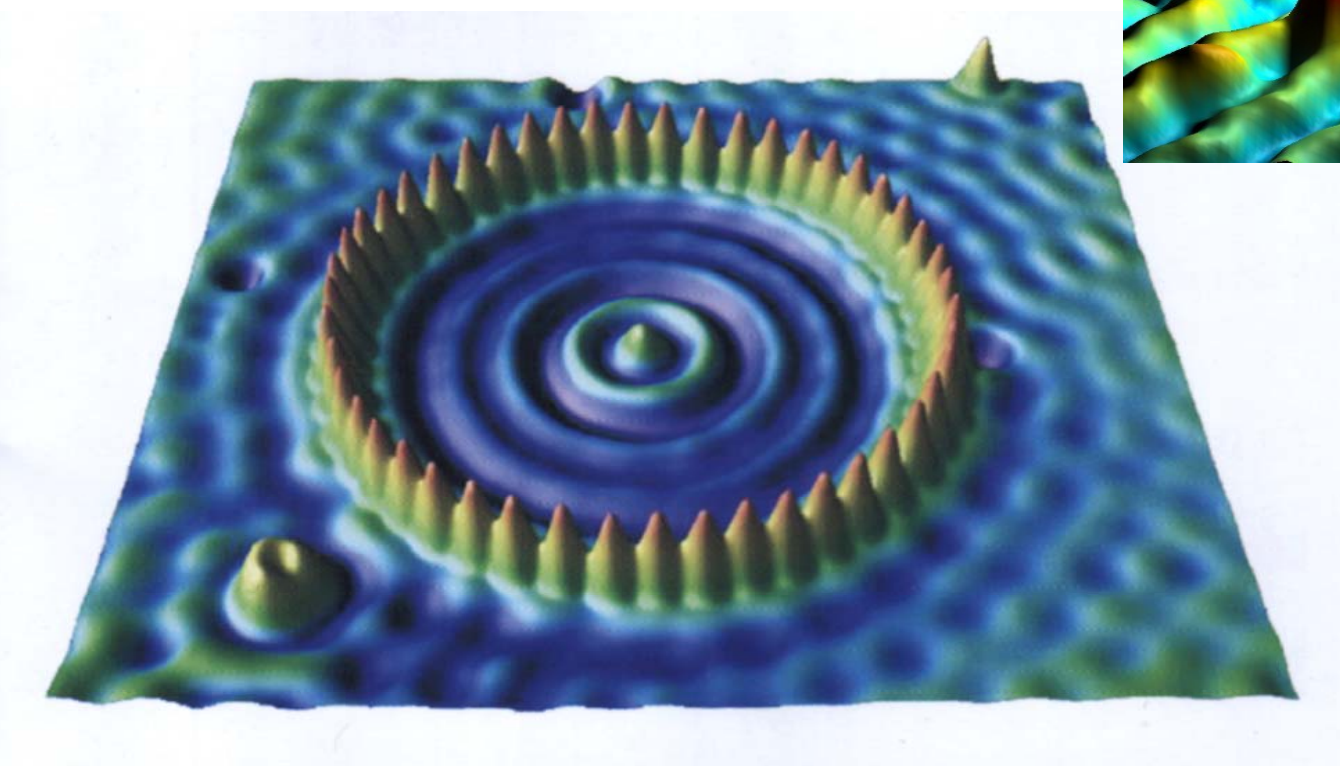
ORDENAMENTO LATERAL DE PONTOS QUÂNTICOS



É possível manipular átomos?

MICROSCOPIA DE TUNELAMENTO

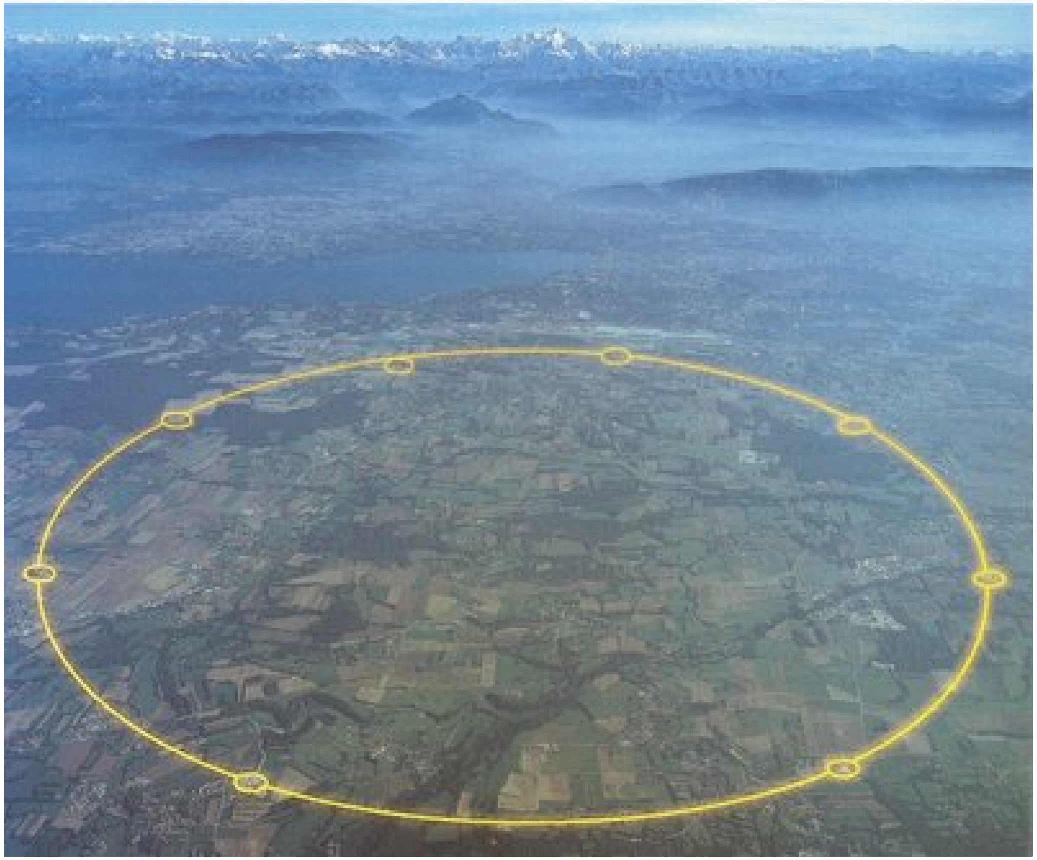


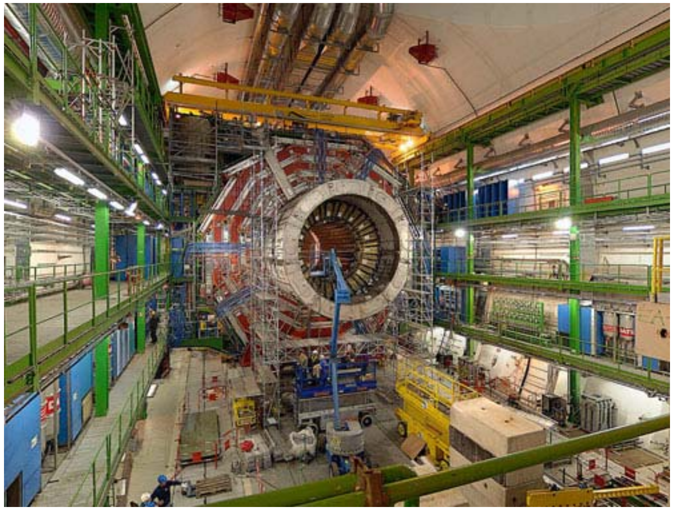


ATÉ ONDE PODEMOS "ENXERGAR" ?

É possível "enxergar dentro dos átomos?

Large Hadron Collider





- “Se, por alguma catástrofe,todo conhecimento científico fosse destruído e somente uma única sentença pudesse ser transmitida para a próxima geração de criaturas.Qual seria a frase que conteria mais informações com poucas palavras?”

FEYNMAN:TODAS AS COISAS SÃO FEITAS DE ÁTOMOS!

FIM