

Feynman's vision

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Motor < 1/64th of an inch

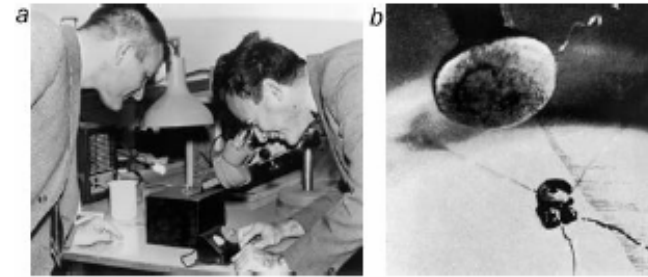
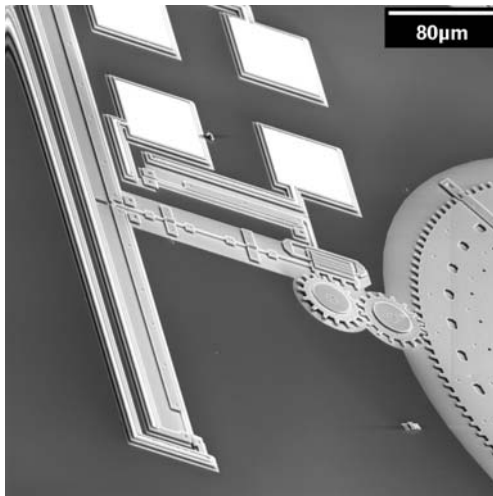
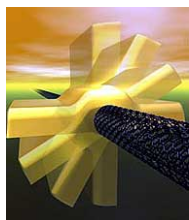


Figure 1. (a) Richard Feynman viewing the micromotor built by William McLellan (left) who won the challenge to build the first motor smaller than 1/64th of an inch. (b) The motor, 3.81 mm wide, photographed under an optical microscope. The huge object above it is the head of a pin. (Picture credit: Caltech Archives)

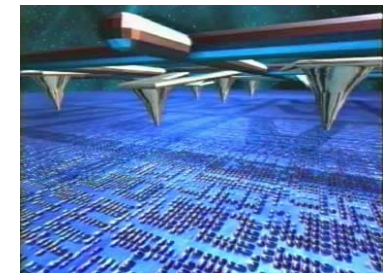
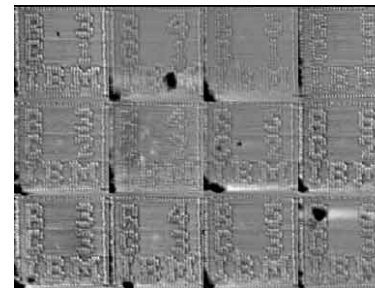
MEMS/NEMS Motors



<http://www.sfu.ca/immr/gallery/motors.html>

Information density

- 1985 using e-beam, "Tale of two cities" inscribed in 1/160mm per side
- Magnetic Disks can approach 60Gbit/in²
- AFM based work at IBM gets 400Gbit/in²



<http://www.zurich.ibm.com/st/storage/millinede.html>

AFM based approach

- Use afm tip to make holes in plastic
- Write:
 - Heat the tip to make a dent
 - thermomechanical system
- Read:
 - Scan with moderately heated tip
 - Detect changes in efficiency of thermal conductance (through changes in resistance) to indicate presence of a dent.
- Slow, but use lots of tips

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Size of all info (10^{15} bits?)

- Using AFM tip:
 - $10^{15} / 400 \times 10^9$
= 2500 sq in. / 93.5
= 26 pages
 - $\sim 40\text{nm} \times 40\text{nm}$ per bit
= 70K atoms per bit
- Using molecular memories/crossbars
 - Fabricated as by HP/UCLA
 - Similar bit density

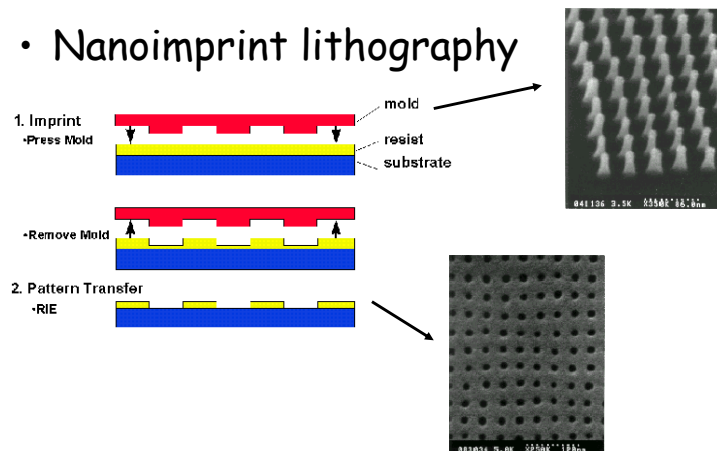
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Writing the bits

- Nanoimprint lithography



<http://www.princeton.edu/~chouweb/newproject/page3.html>

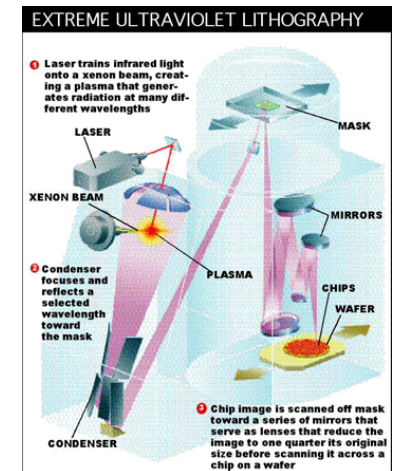
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Writing the bits

- Nanoimprint lithography
- Photolithography



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Writing the bits

- Nanoimprint lithography
- Photolithography
- E-beam litho



<http://www.nanophys.kth.se/nanophys/facilities/nfl/sem-ebeam.htm>

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Bio-inspiration

- Biology is one of the main inspirations for all nanotechnologists
- Self-assembly
 - Protein formation
 - differentiation
- Density of information
 - 1 base pair 2-3nm
 - 50 atoms per bit
- Energy system
 - Atp motor
 - Ion pumps

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Bio

- Inspired by us!
- But, be careful with biomimetic approaches

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A Better Microscope

www.chimica.unige.it/membrane/eng/in

- SEM
- TEM
- STM
- AFM



<http://sibener-group.uchicago.edu/facilities.html> <http://www.mos.org/sln/SEM/gallery/>



<http://www.semitech.ee.ttu.edu/html/facility.html>

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<http://sibener-group.uchicago.edu/facilities.html>

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Size/parallelism/scale

- The $\frac{1}{4} \frac{1}{4} \frac{1}{4}$ argument?
- Precision and scaling
- What are some ways to deal with imprecision?
- Are things really the same, only smaller?
 - Surface/volume
 - Van der Waals ($\propto r^{-6}$)
 - Quantization
 - Thermal
 - Conductance
 - Adsorption

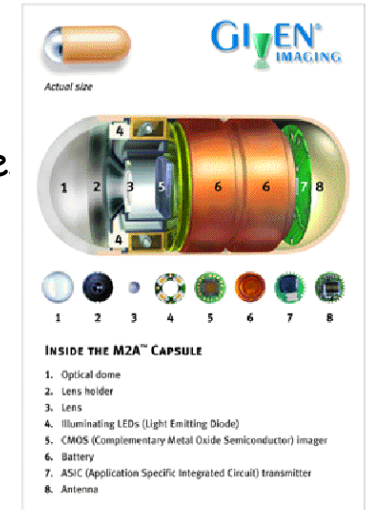
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Nanomedicine

- Not exactly nano, ...
- Cancer treatments based on nanoparticle



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Molecular Manufacturing

- The drexlarian nanotechnology
- Placement of individual atoms
- Is this possible?
- If so, what are the benefits?

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Plan

- Introduction
- Feynman's lecture
- Forces at the nanoscale
- More Forces
- Microscopy (SEM, TEM, AFM, STM)
- no class on 9/16
- manipulation (AFM/STM/other)
- nanomaterials
- guest lecture (materials)

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Plan

- CNT
- nanoelectronics (devices)
- nanoelectronics (wires & assembly)
- guest lecture (vlsi)
- nanocomputing
- design space 1
- nano/bio
- molecular machines
- bottom-up/self- assembly
- ethics

Plan

- ethics
- design space 2
- guest lecture
- guest lecture
- light and the nanoscale
- design space 3
- swarms
- projects

For next time

- Read chapter 1 of "Nanotechnology: Basic Science and Emerging Technologies" by Mick Wilson et al., CRC Press (2002)
- Begin design space exploration
 - Create a web page with links to 10 different companies pursuing nanotechnology. For each provide a brief summary of what they are doing and what forces, size scales, manufacturing methods, etc. they are exploiting



Mechanics of submission

- Send Brent a link to your page by Monday 5pm. He will link all the pages together and look at them before class.