Materials for the 21st Century:

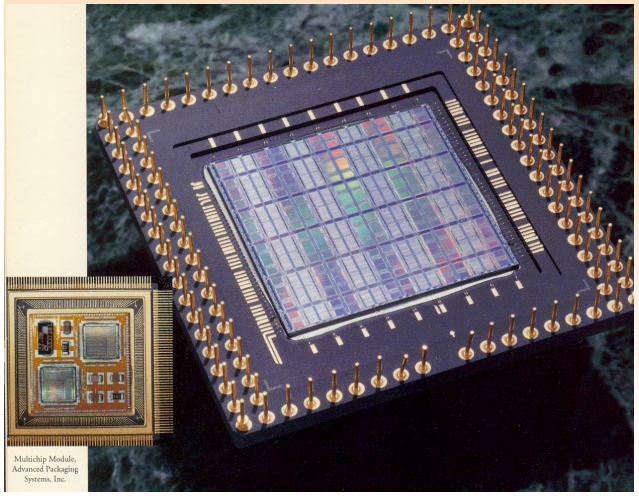
A Revolutionary

--Not An Evolutionary--

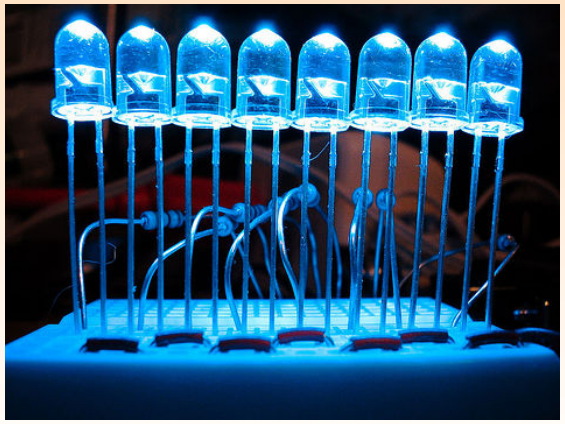
Approach

The Thrill of Discovery and Innovation

Materials in your life!



Integrated Circuits.

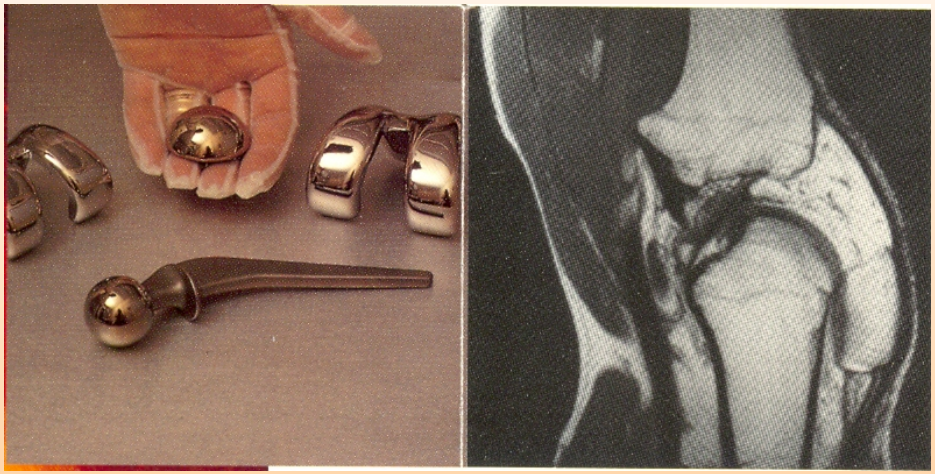


Light Emitting Diodes

Composite Skis, DuPont

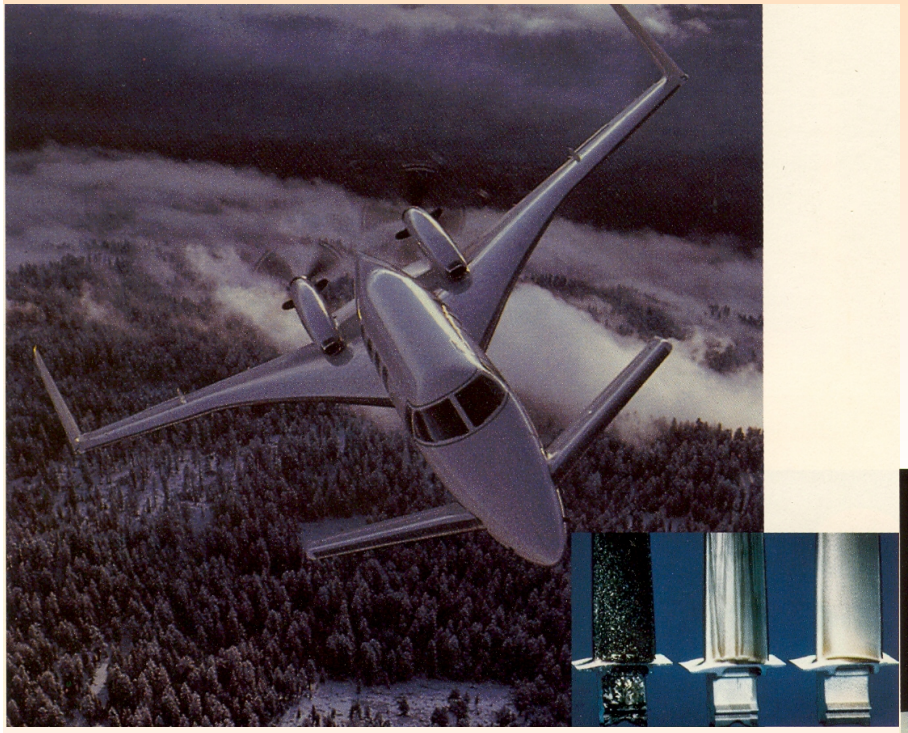
Kevlar–Reinforced Tennis Rackets, DuPont

Artificial Body Parts: MRI imaging



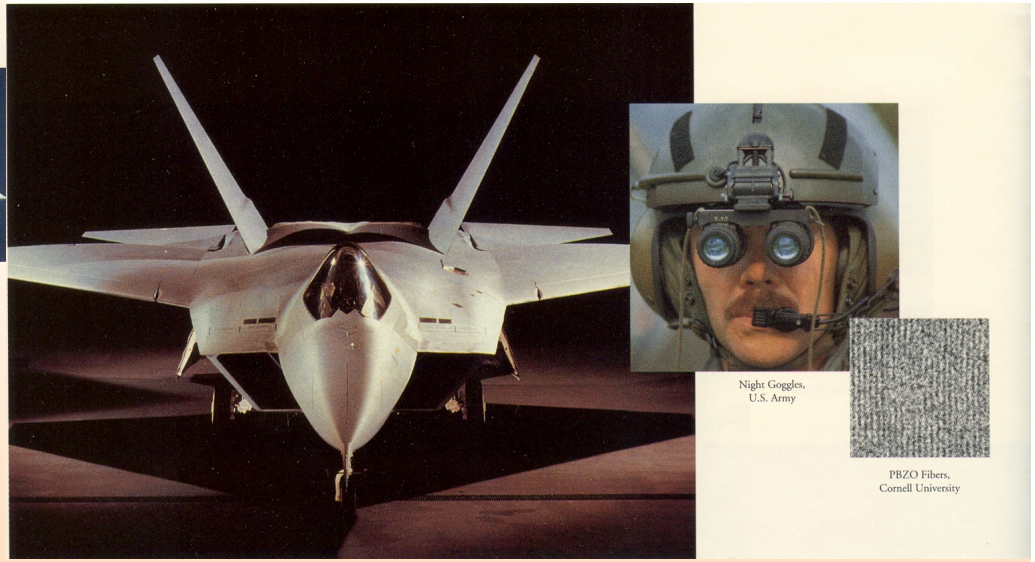
Recreation

Materials in your life!



Transportation:

- Light weight: Polymers-composite Materials
- High Temperature NiAl turbine blades

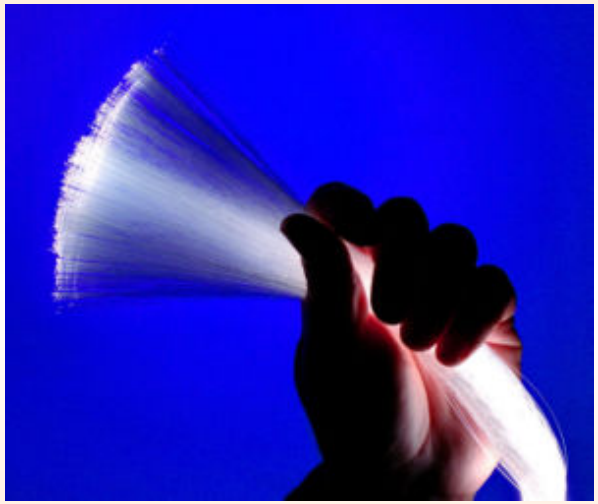


Defense:

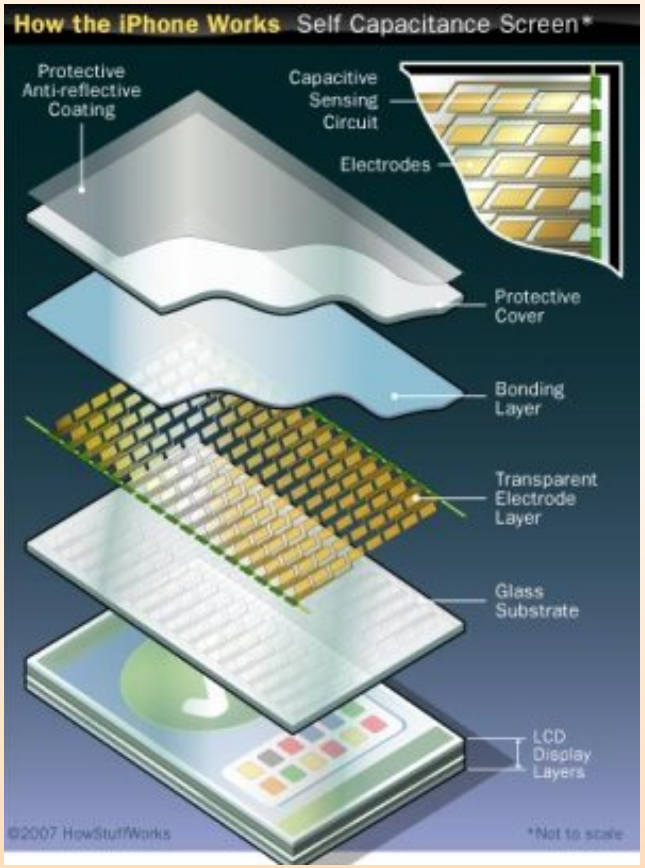
- Light weight: Polymers-composite Materials
- Night Vision goggles.

Materials in your life!

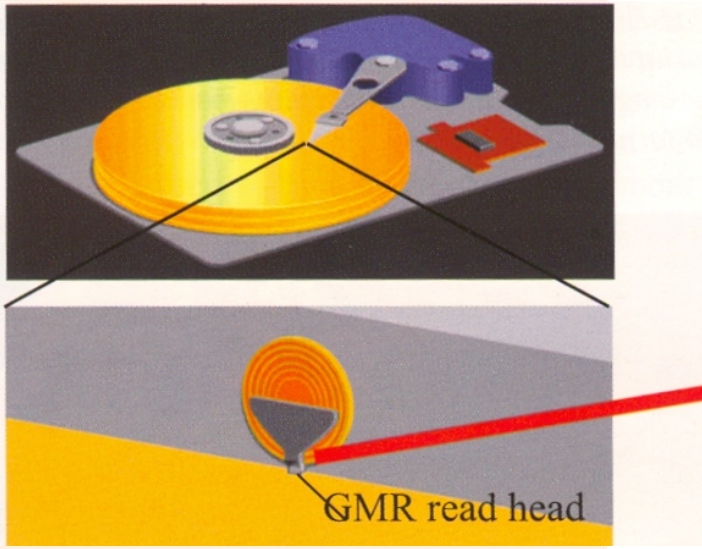
Information Technology



Fiber Optics

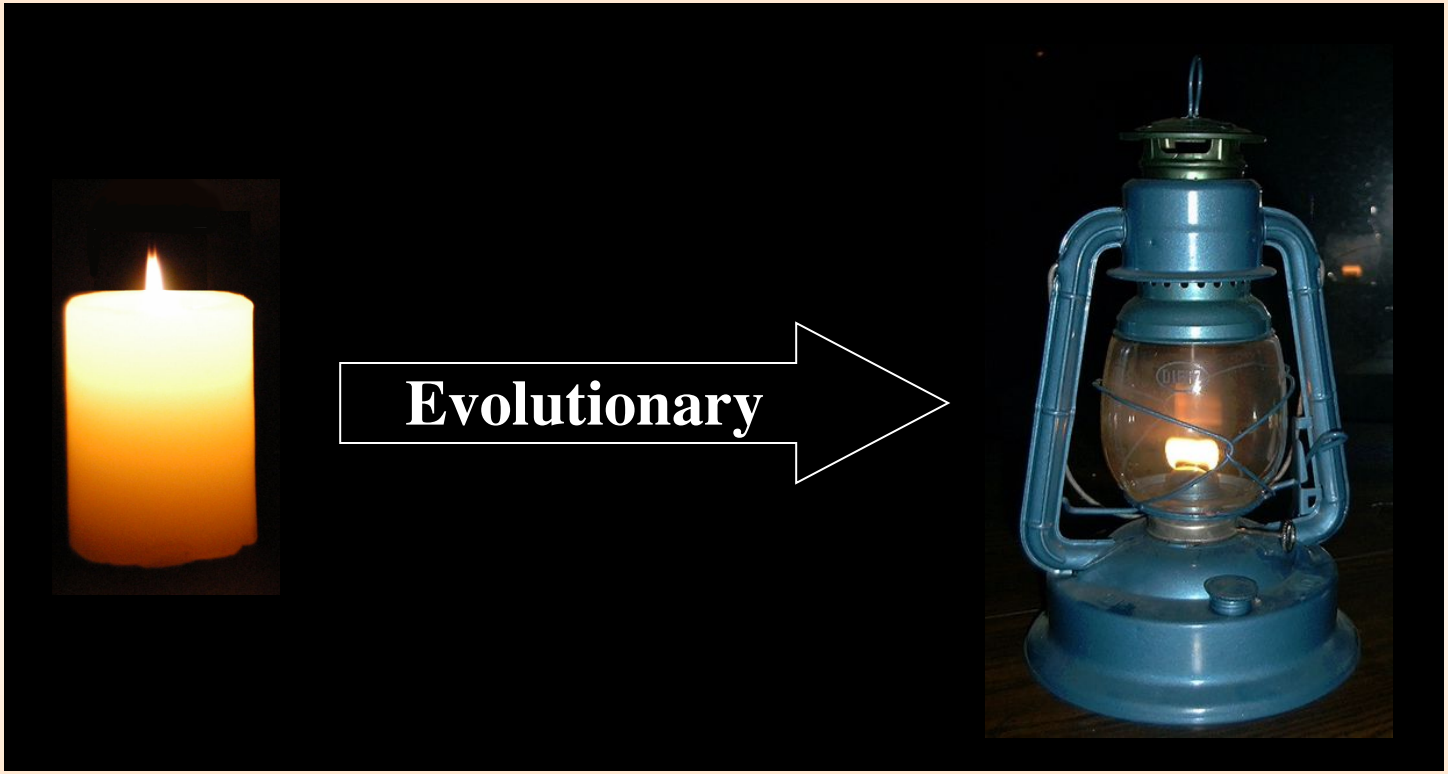


iPhone

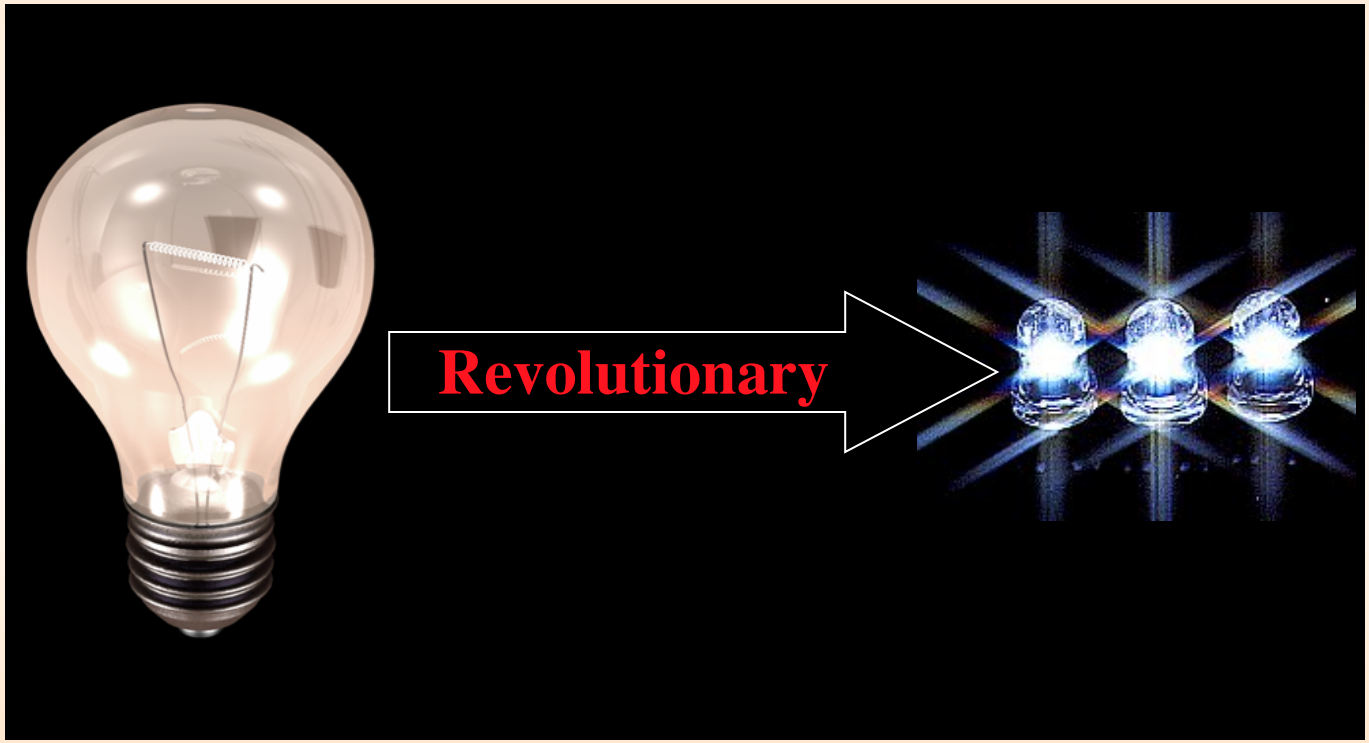


GMR read head

Light



Light



Nobel Physics 2009: Information

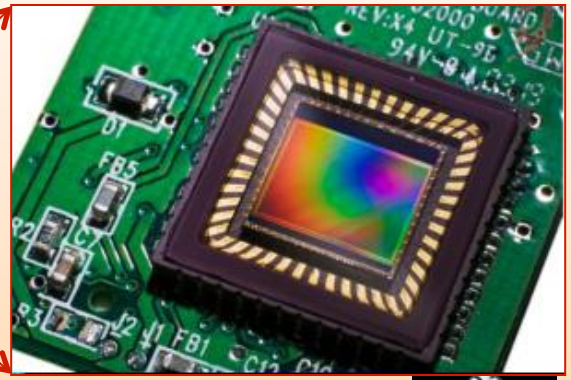
This is Evolutionary Science!

for groundbreaking achievements concerning the transmission of light in fibers for optical communication
for the invention of an imaging semiconductor circuit – the CCD sensor

Kao

Boyle

Smith

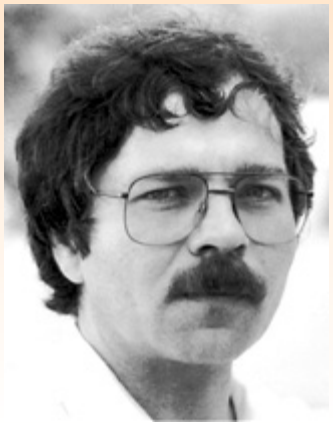


Women in Physics

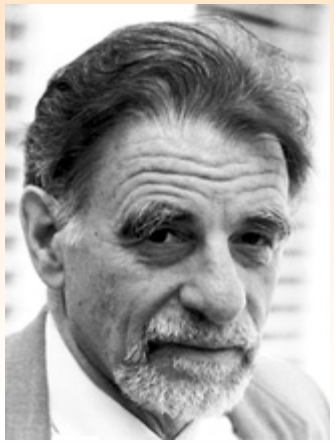
Nobel Physics 1987-Discovery 1986

for their important break-through in the discovery of superconductivity in ceramic materials

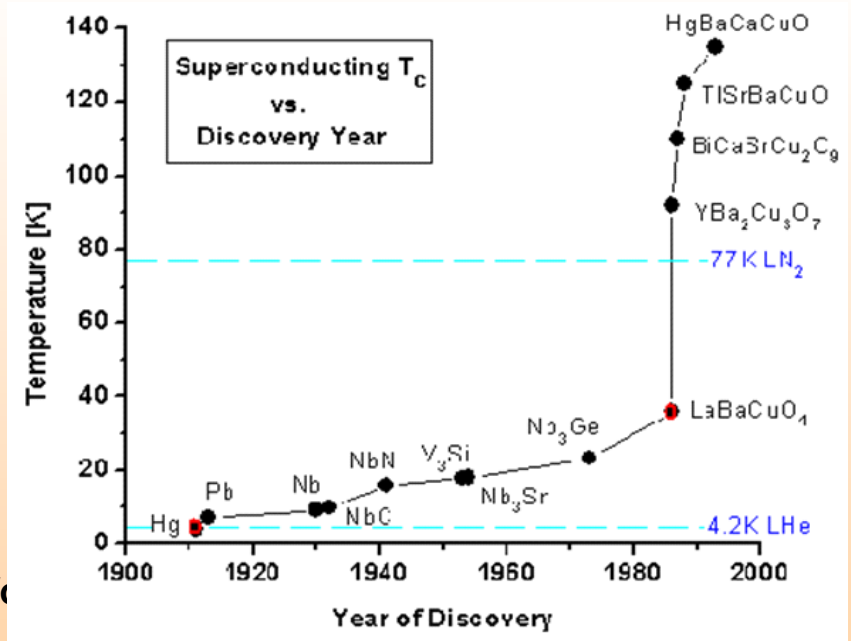
This is Revolutionary!

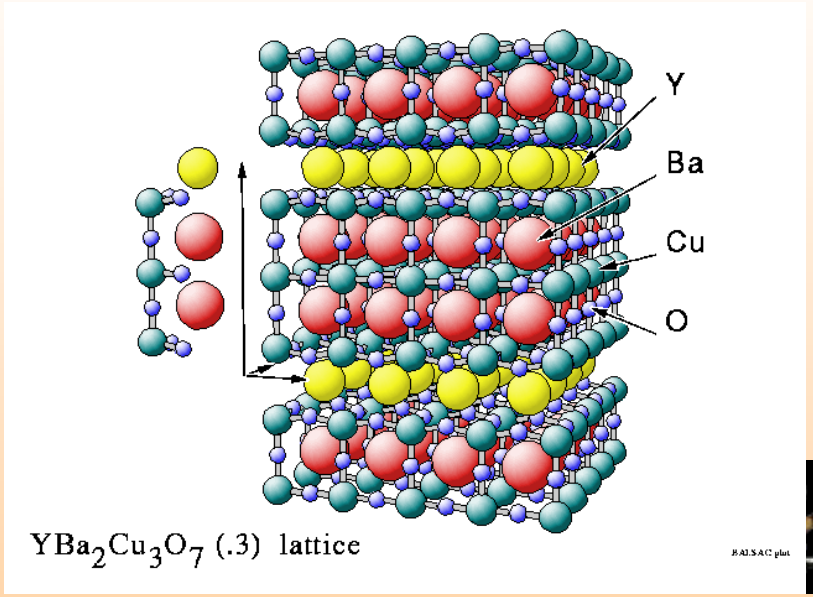


J. Georg Bednorz



K. Alexander Müller





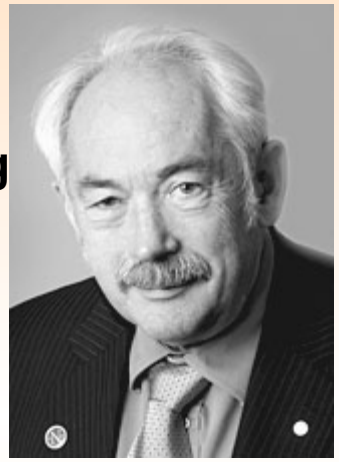
Nobel Physics 2007:

Revolutionary!!

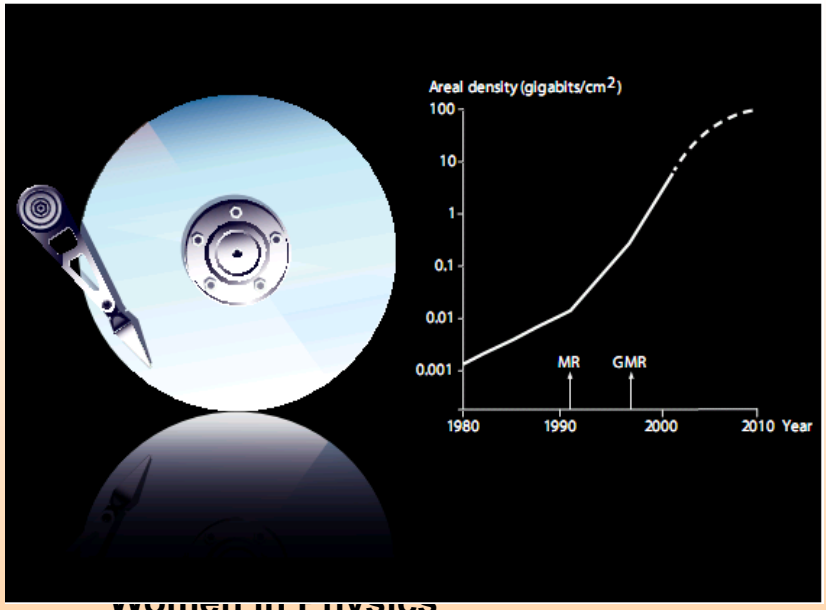
for the discovery of Giant Magnetoresistance:GMR

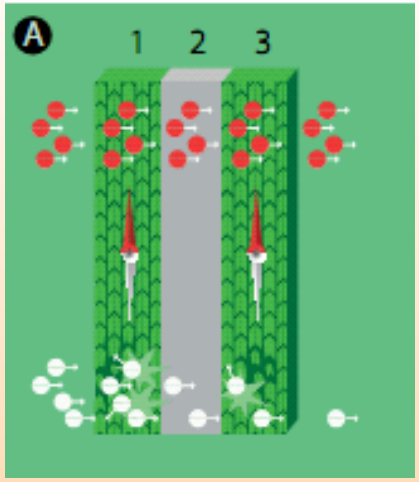
Fert

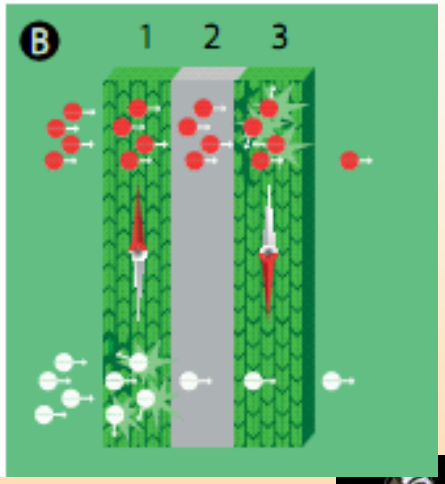
Grünberg



Ten years from discovery to the market place

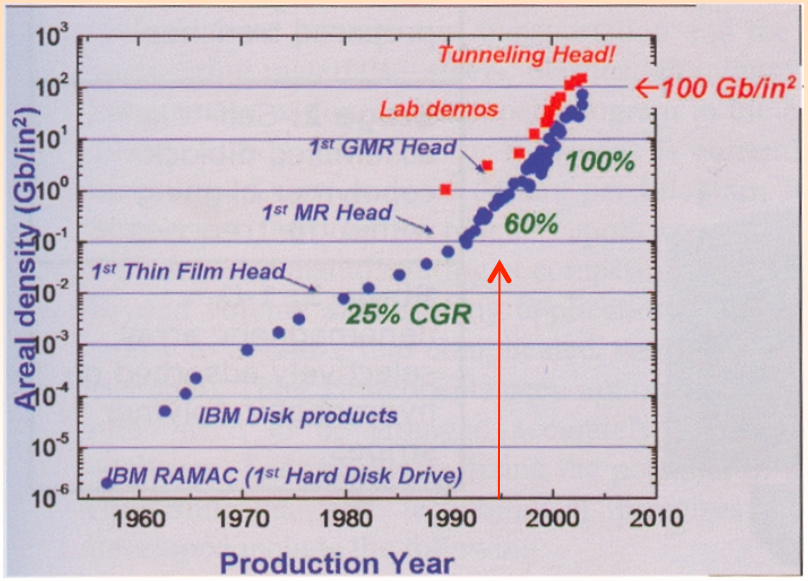




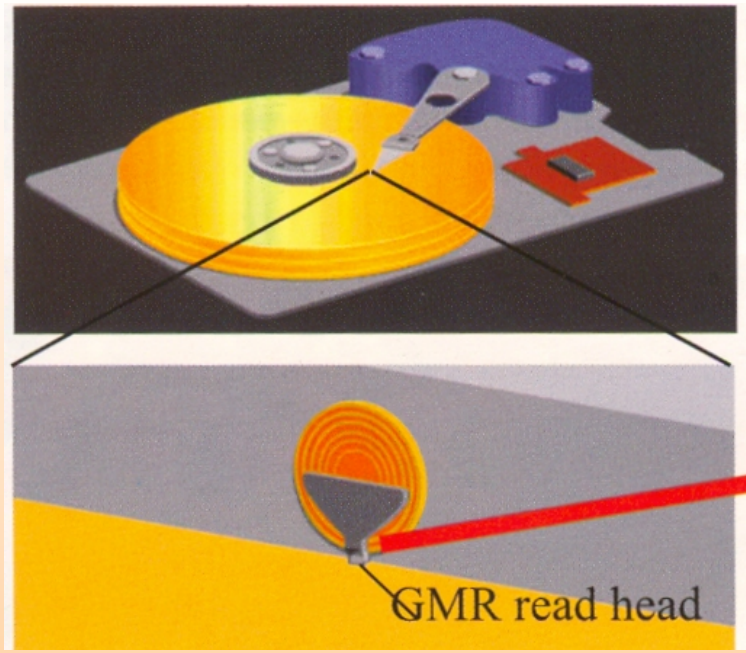


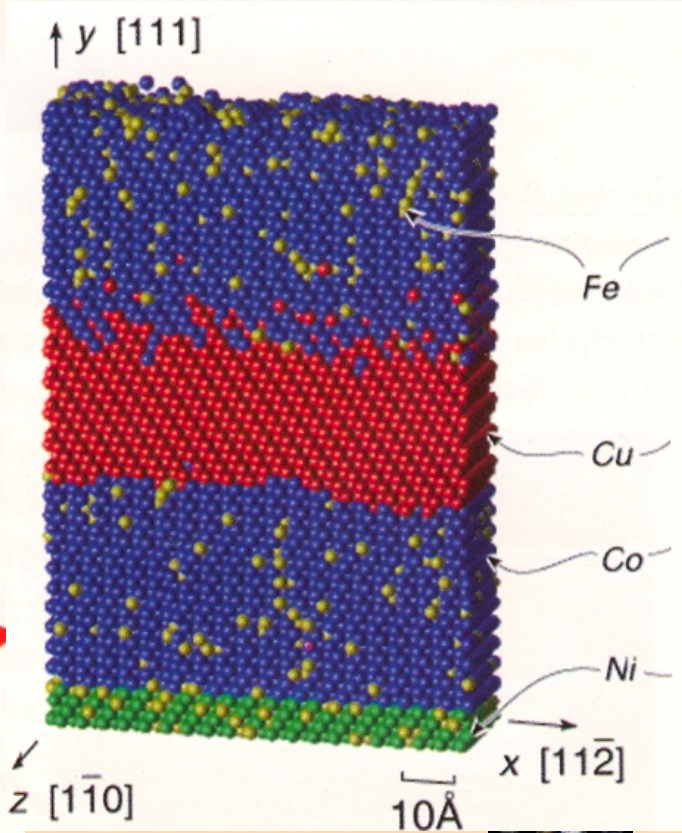
Women in Physics

Nobel Prize: Giant Magneto-resistance



Discovered 1988-1989
In the market by 1997





Nobel Physics 2010: Discovery

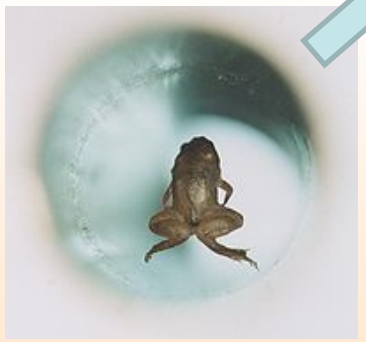
for groundbreaking experiments regarding the two-dimensional material graphene

Andre Geim

Konstantin Novoselov

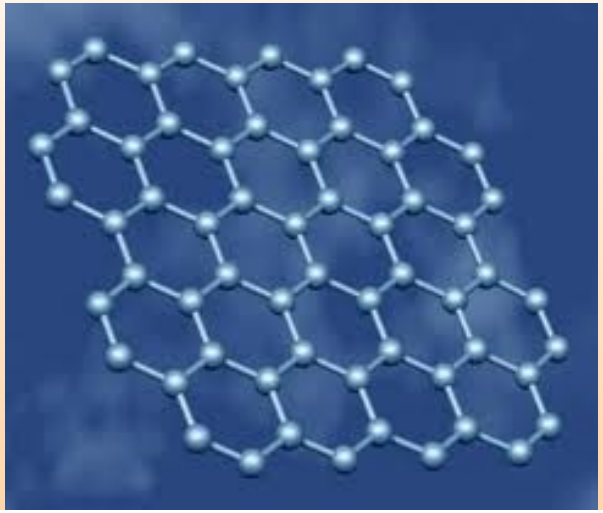
Design to Discovery:

Discovery to the Market Place???



IG (Ignoble) Nobel Prize in physics 2000: Magnetically levitated live frog

Women in Physics



Let's Have Fun Predicting the Future
New materials in 21st Century

Material by Design

A marriage of Evolutionary and Revolutionary approaches

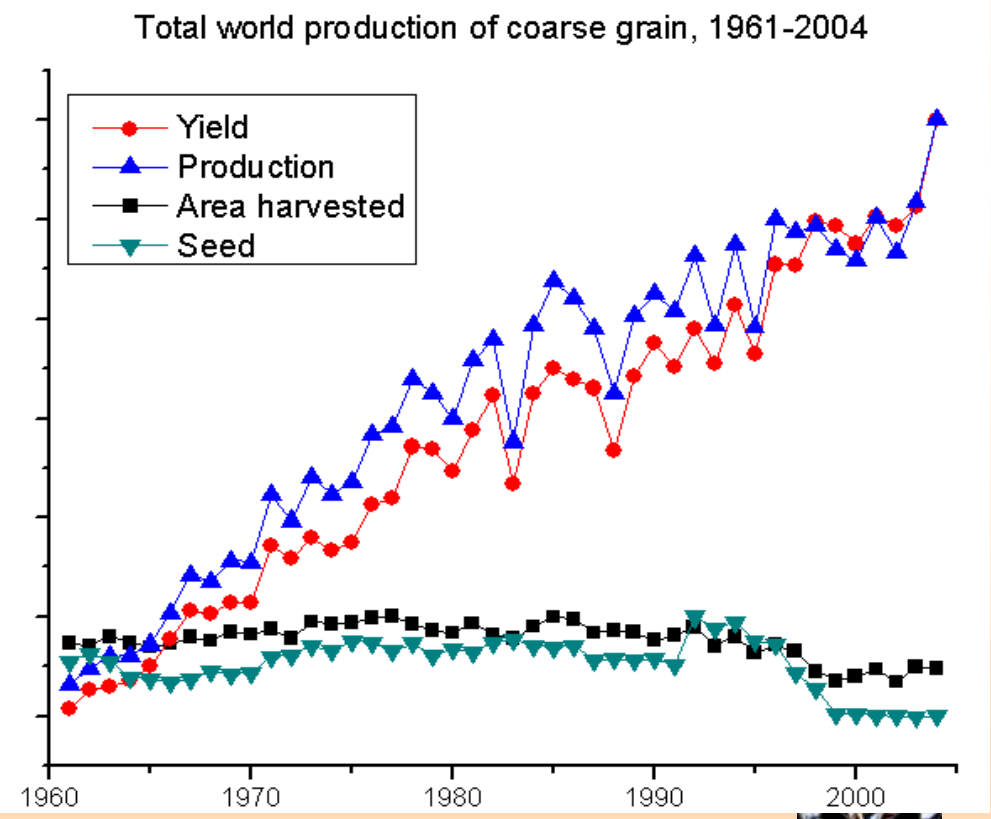
Women in Physics

Dangers of trying to Predict the Future

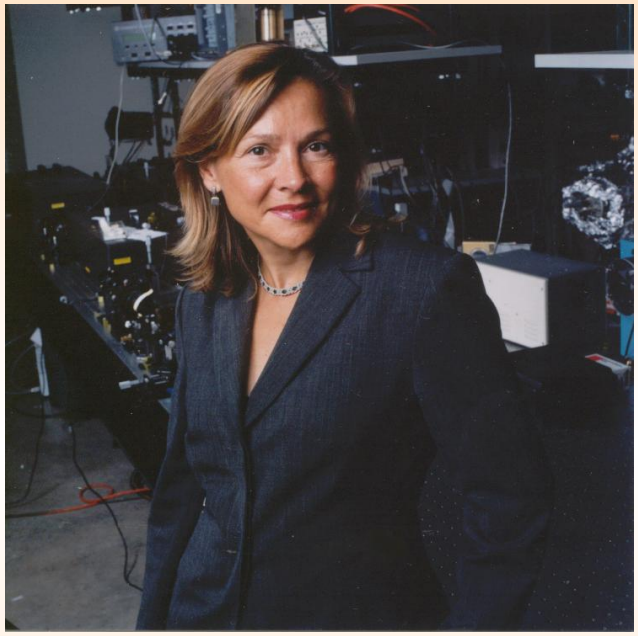
Paul Ehrlich: 1968

"The battle to feed all of humanity is over... In the 1970s and 1980s hundreds of millions of people will starve to death in spite of any crash programs embarked upon now."

Norman Borlaug received Nobel Prize for his development of disease resistant, high yield wheat in 1970!



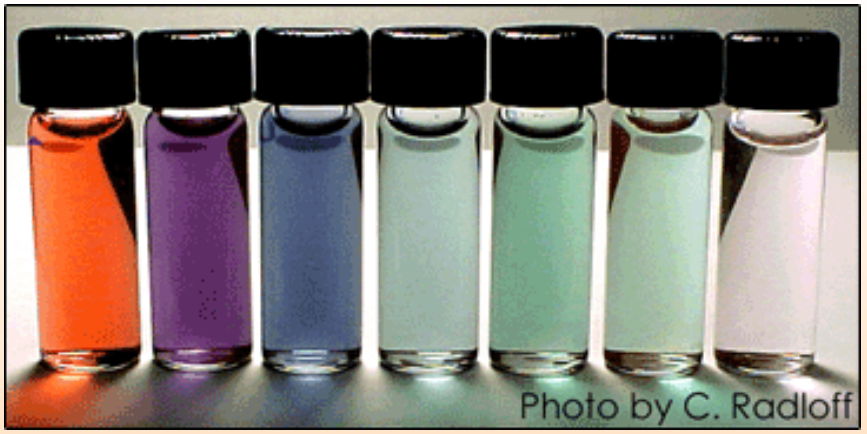
Materials by Design for Medical Applications: Passive Targeting Cancer



Naomi Halas

Stanley C. Moore Professor in Electrical and Computer Engineering and Professor of Chemistry at Rice University

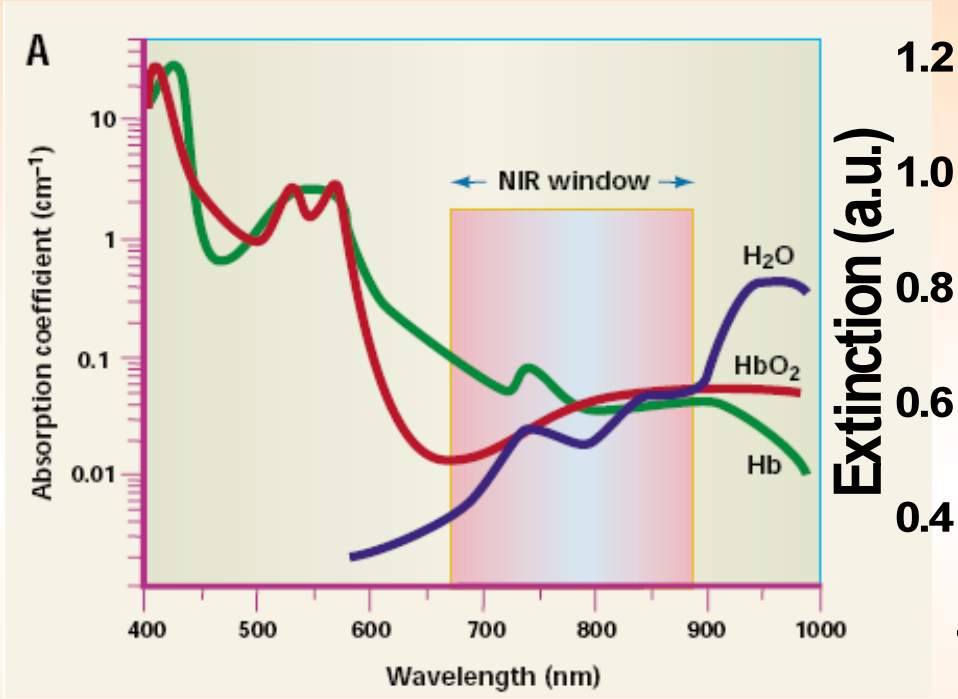
Nanoshells (110nm silica core, 10nm Gold shell) injected into mice with tumors. Laser light heated nanoshells to 50°C killing tumors. Resonate excitation of plasmons.

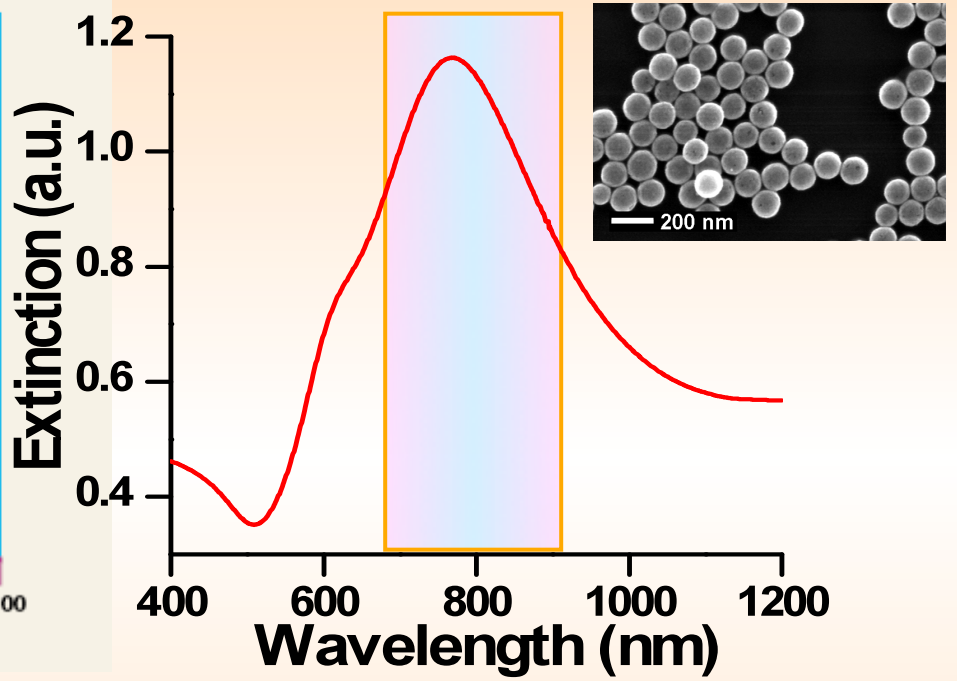


Size Separation Nano-Particles

Tuning Plasmon Resonances in Nanoshells

Tune the size of nanoparticle

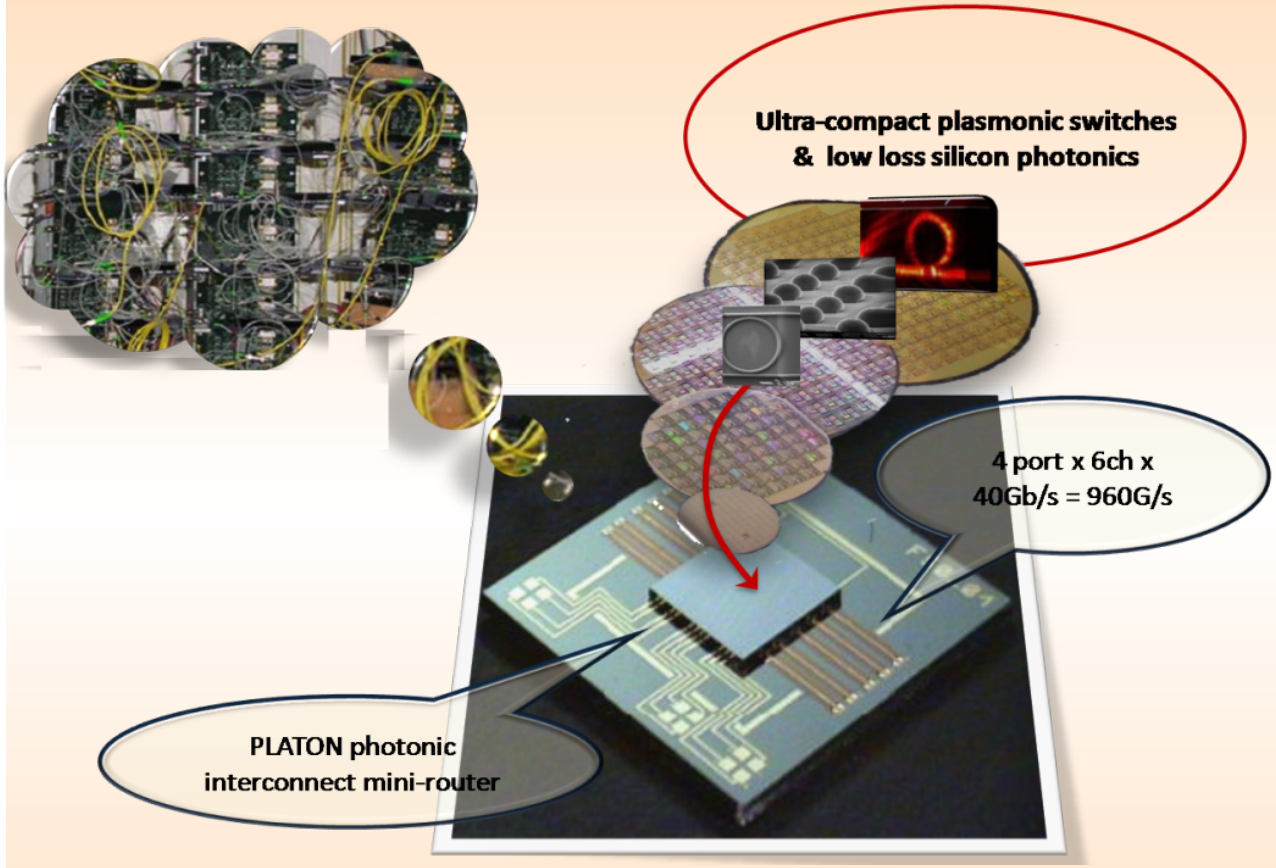




Weissleder et al., Nat. Biotech. 2001, 19, 316 - 317

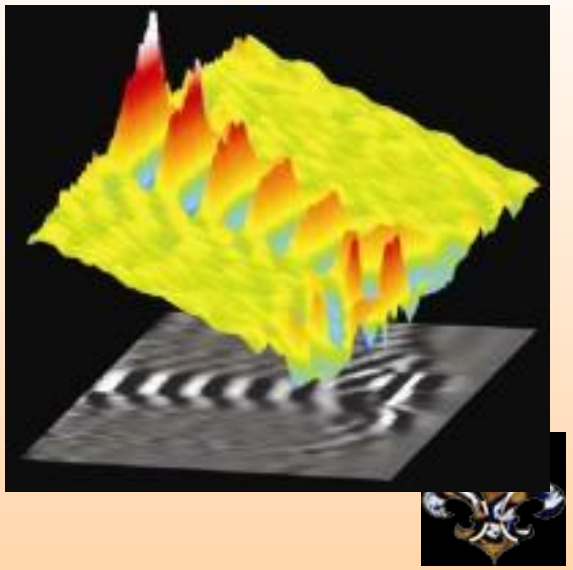
- Tissue is maximally transparent
- light scatters but penetrates relatively deeper into tissues: ~ 10 cm, depending on tissue type
- Minimal photodamage to living cells

Plasmonics



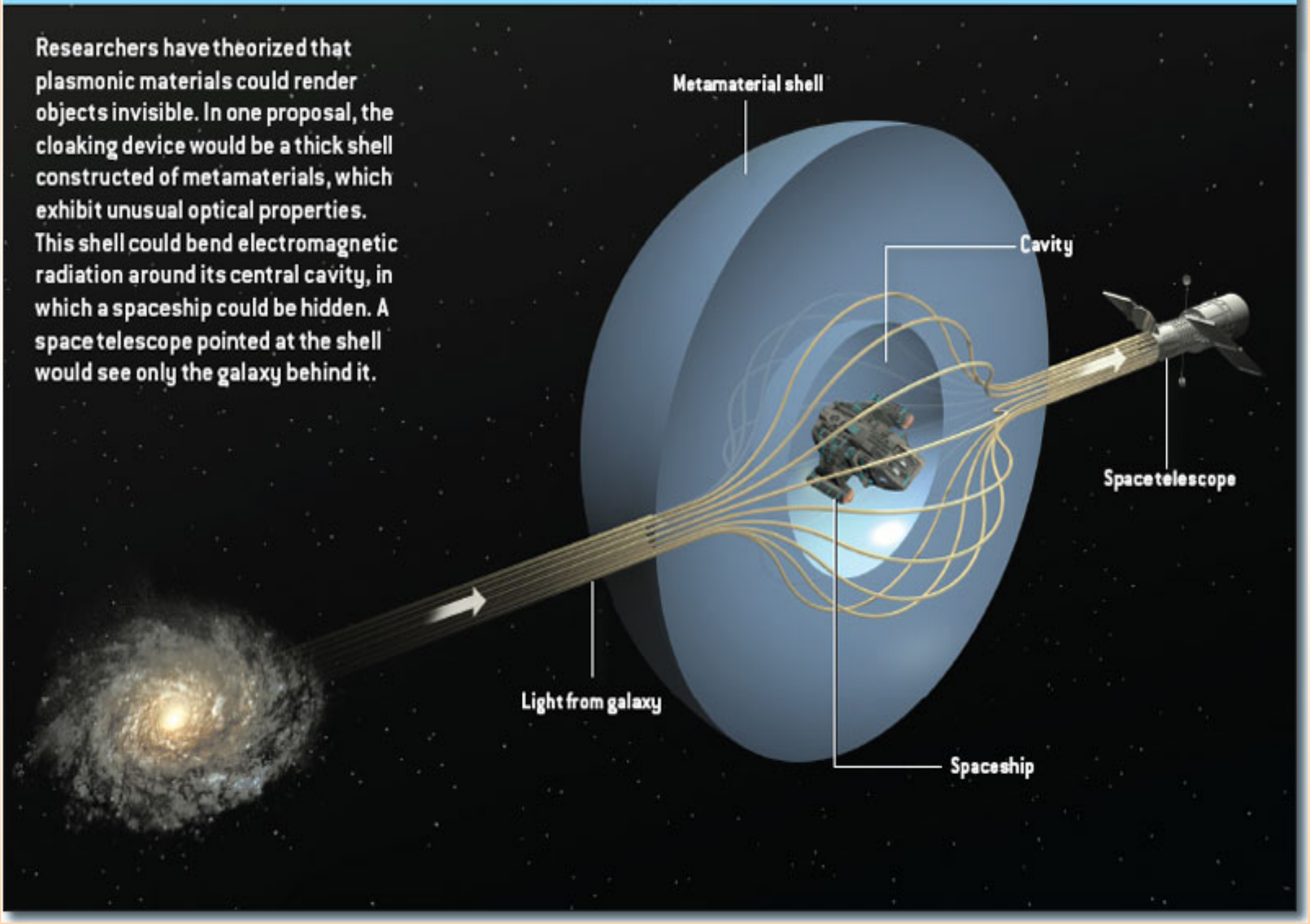
Use plasmonics for the interconnects.

Picture of plasmonic wave moving at almost the speed of light.



HOW A CLOAKING DEVICE MIGHT WORK

Researchers have theorized that plasmonic materials could render objects invisible. In one proposal, the cloaking device would be a thick shell constructed of metamaterials, which exhibit unusual optical properties. This shell could bend electromagnetic radiation around its central cavity, in which a spaceship could be hidden. A space telescope pointed at the shell would see only the galaxy behind it.



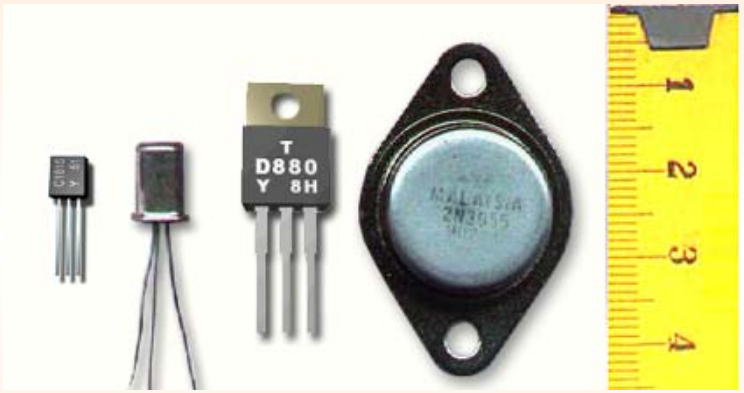
Prediction: 21st Century Nobel Prize???

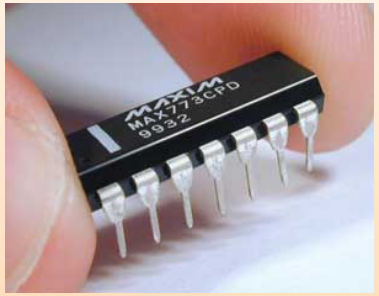
Sir John Pendry
1943—
British

MIT talk: http://mitworld.mit.edu/video/455
Knighted by the Queen—2004, "for service to science."
J. G. Pendry, "Negative Refraction Makes a Perfect Lens," PRL, 85, 3966 (2000).
Interview: http://www.youtube.com/watch?v=LEaCLxsdxOU

Information Technology

First Transistor, 1947
(Bell Labs)





Integrated Circuit

--1996 smallest feature 500nm
--2006 smallest feature 90nm
--Moore's law: Density doubles every 18 months
--Prediction: 10 times better in 4 years

Women in Physics

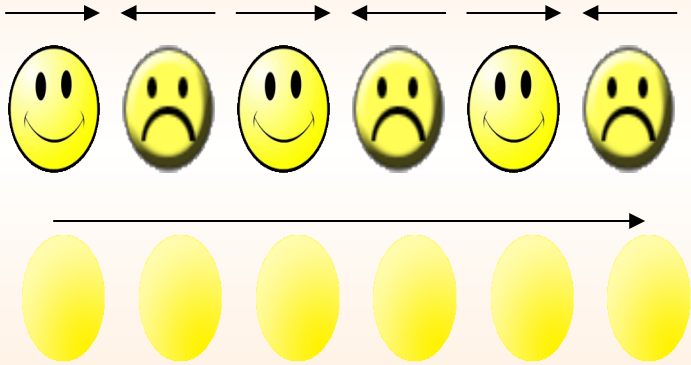
Spintronics

A Revolutionary Approach Information Technology: Use the spin of the electron not the charge

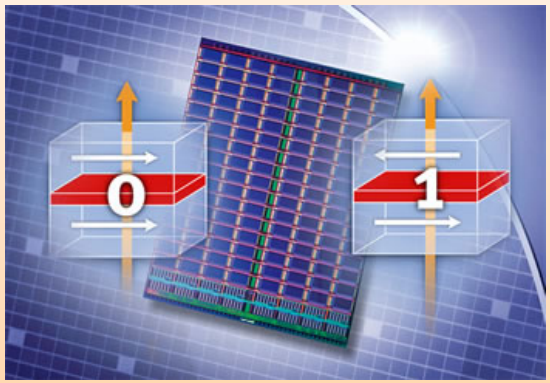
ORNL Supercomputer 10MW power: 2% of Knoxville

Spintronics Advantages

- Fast
- No power dissipation
- Non volatile memory

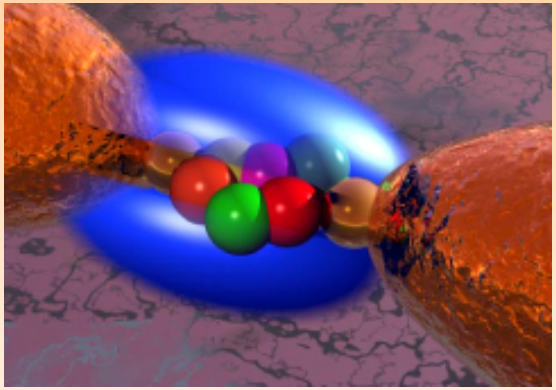


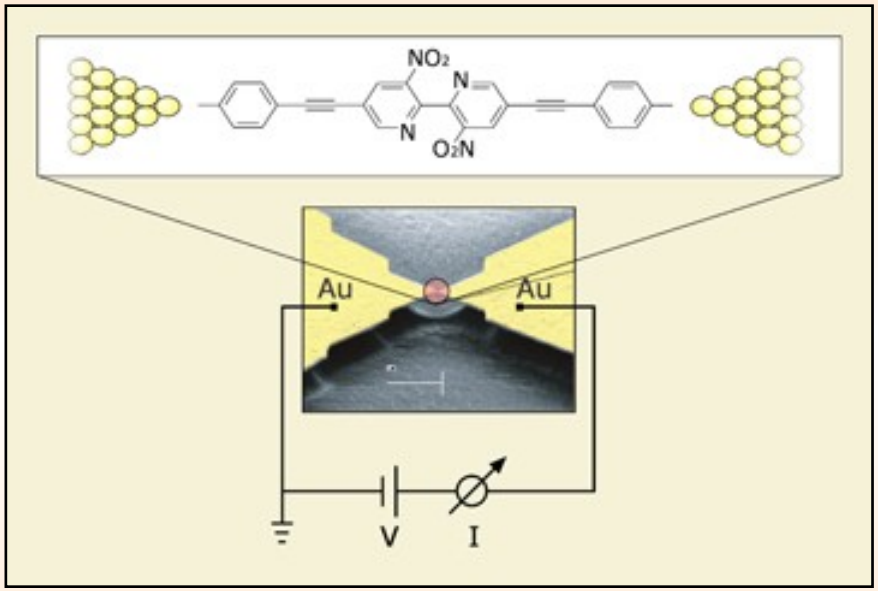
- **Magnetic Semiconductors-No!**
- **Conventional Magnetic Materials??**
- **Artificially structured materials -Yes**



MRAM computer chips use electron spin rather than charge to store bits of data, which enables them to retain information even when electrical power is turned off. (From Lawrence Berkeley National Lab)

Information Technology
The Future??
Molecular Electronics





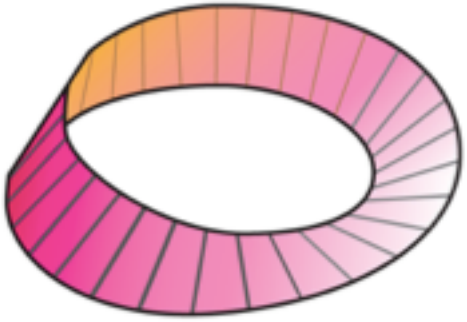
"A single molecule can be switched between two distinct 'on' and 'off' states. Organic molecules measuring only about 1.5 nanometers in length have been used."

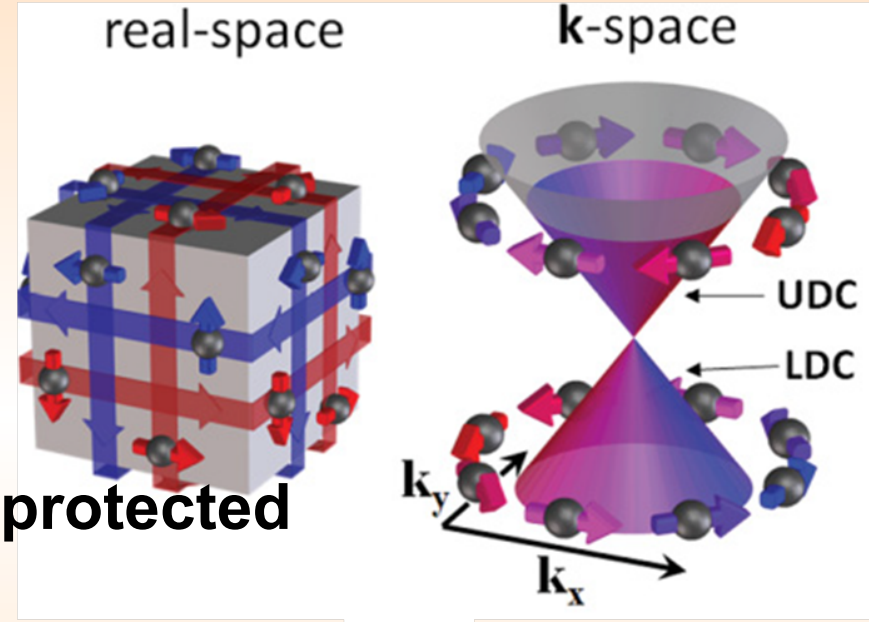
50-100 times higher density

A supercomputer based on molecular electronics would comfortably fit in the palm of your hand and use very little electricity.

All of the information stored in the Library of Congress could be contained in a memory the size of a sugar cube.

Topological Insulators—Quantum Computing





Surface States Topological protected
Theory Driven field!

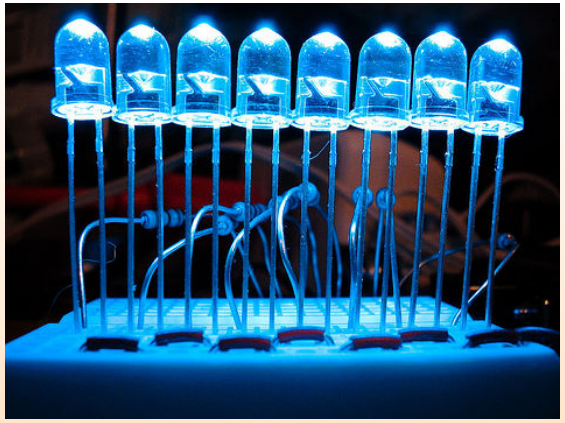
Rongying Jin
Professor of Physics
Louisiana State University

Jonathan Dowling
Louis Haber

Women in Physics

Energy

- More efficient use!
- New Sources!
- New Materials—Discovery and Design.
- Protect our environment!

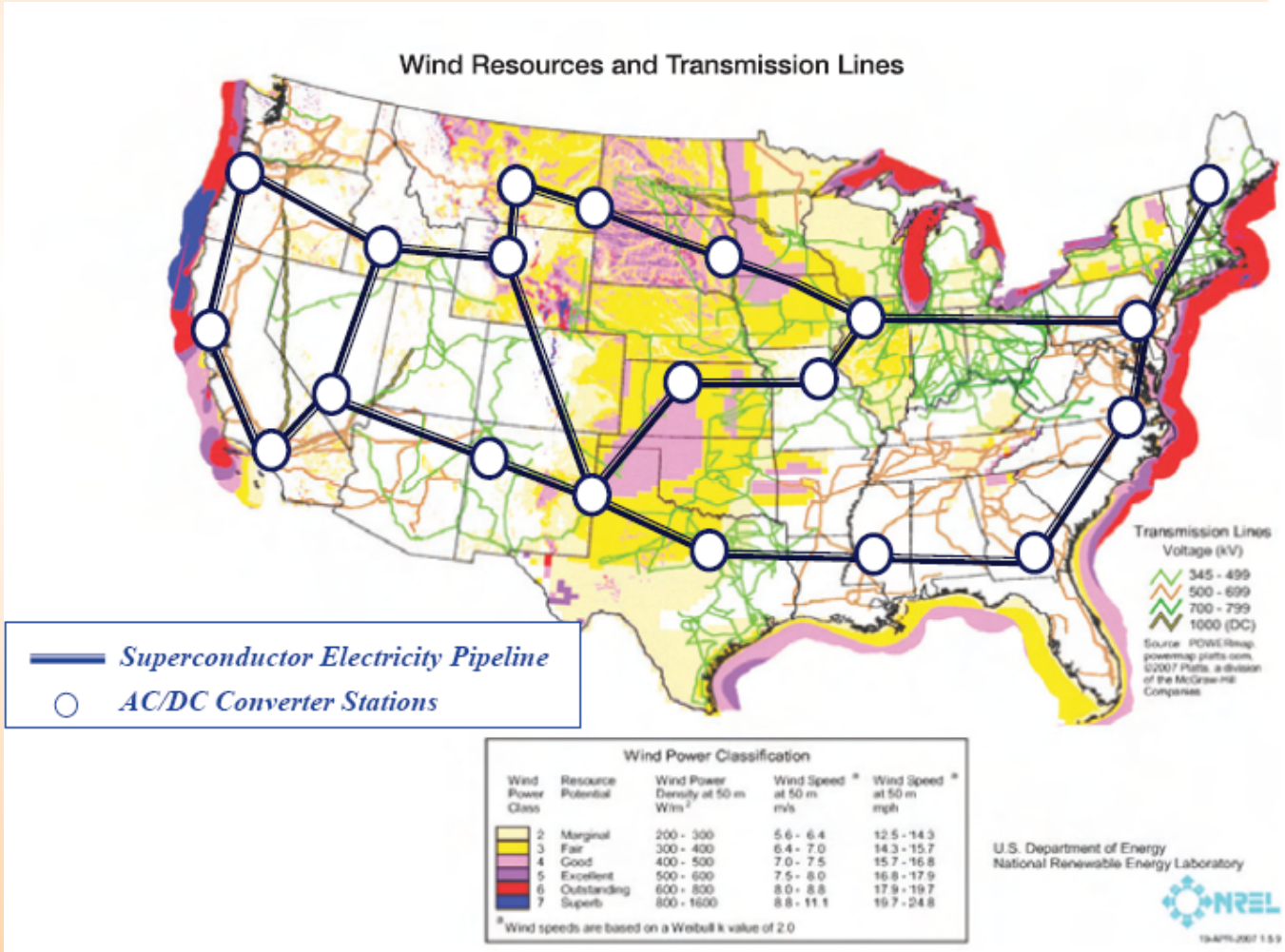


Light Emitting Diodes

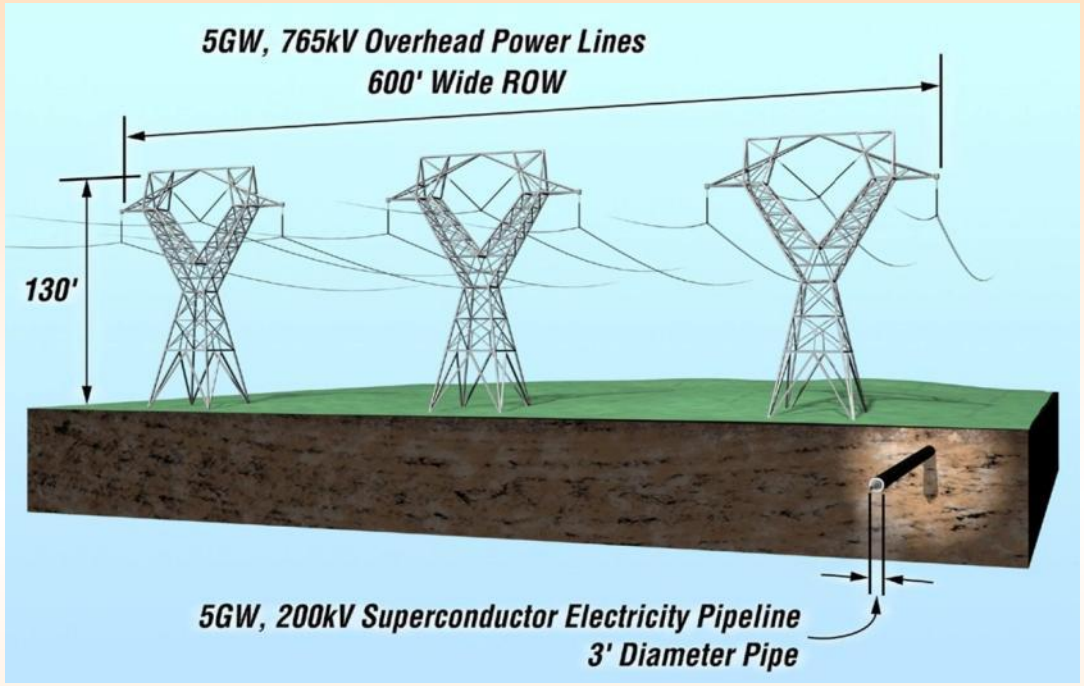
Envisioned "Superconducting Electricity Pipeline"

- High-current (100 kA), low-voltage (200 kV)
- Compatible with multi-point voltage converters (interconnection with 3 existing AC grids)

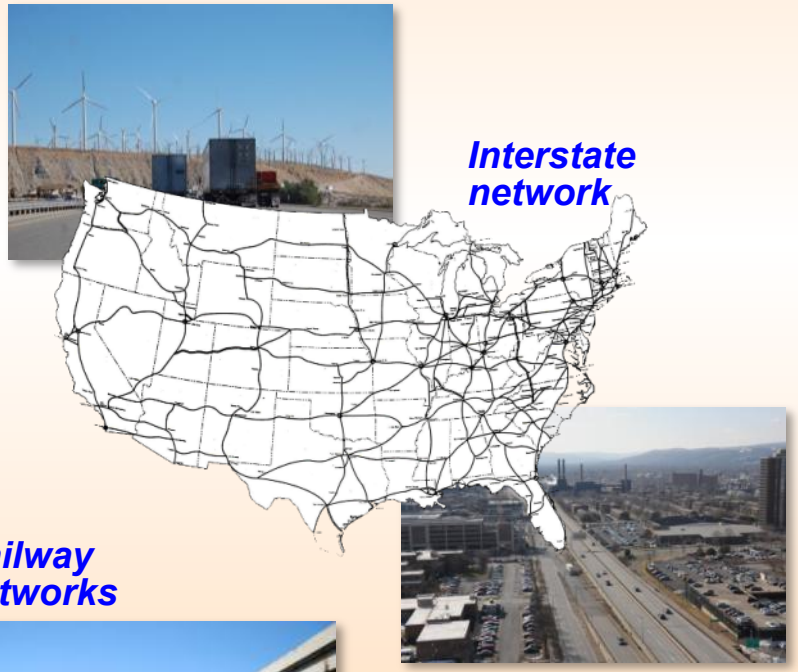
Concept tested



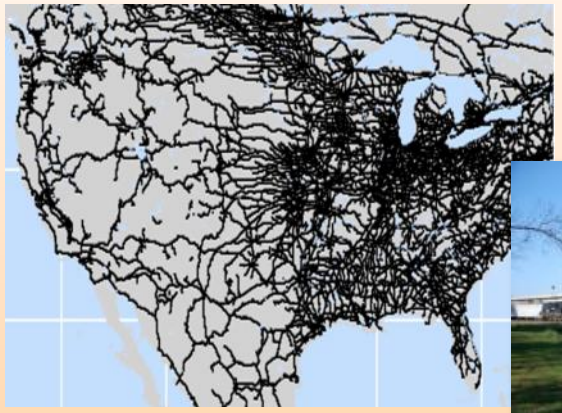
HTS simplifies right-of-way implementation barrier for conventional cables



Right of way for superconducting DC cables exist in the form of extensive networks of interstate highways…



Interstate network



Railway networks

… and is augmented by close proximity to extensive rail network.

Women in Physics

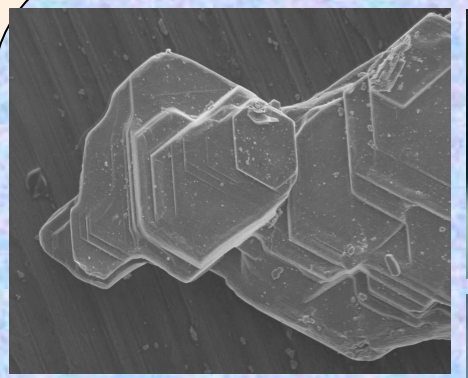
Rongying Jin

Associate Professor of Physics
Louisiana State University

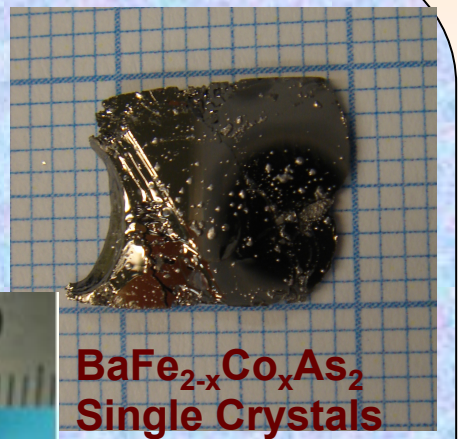
Advanced Materials for Energy

- **Superconductors**
  (transmission of power without any loss)
- **Thermoelectric materials**
  (conversion of waste heat into electric power)

Women in Physics



1st Superconducting Crystal of $Na_{0.3}CoO_2$--$1.4H_2O$

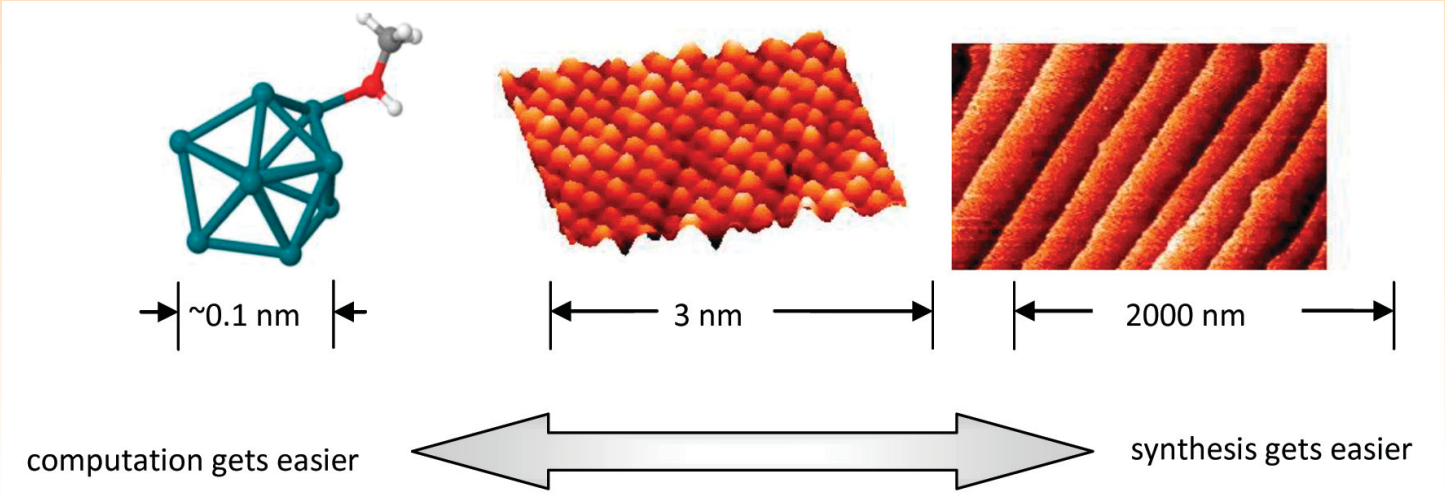


$Ca_{2-x}Sr_xRuO_4$

DOE ” Energy Center at LSU “Theoretical investigations guiding experimental research on Catalysis.

Center for Atomic-Level Catalyst Design

J. Spivey, Director



RESEARCH PLAN AND DIRECTIONS

To develop next-generation computational and synthesis/ characterization tools to engineer solid catalysts for energy-related conversion processes.

Dream: Design a catalyst for dry reforming, conversion of CO_2 plus natural gas or Methane to synthesis gas and then to a liquid transportation fuel.

--Utilize 1.1 billion metric tons/yr of CO_2
--Increase the use of Coal
--Reduce US dependence on foreign oil to zero

Women in Phys

Thank You

This was Fun!

CO_2 Reduction Pathways

S. Sinnott (UF)

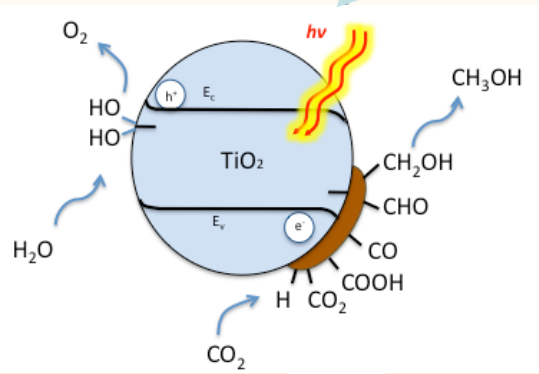
J. Flake (LSU)

CO_2

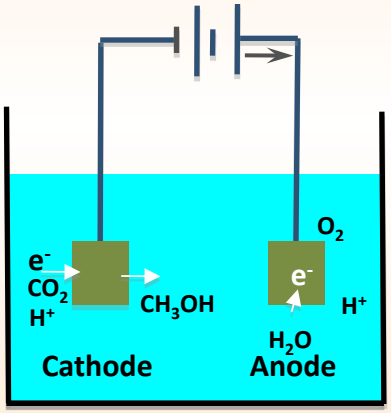
Solar

H_2O

PV or wind to electrical



Photoelectrochemical



Electrochemical Reduction

Photosynthesis

Fuels

$$CO_2 + 6H^+ + 6e^- \leftrightarrow CH_3OH + H_2O$$

E_o = 0.020 V vs. SHE

Women in Physics

The Grand Challenge

Materials for the 21st Century: Materials by design

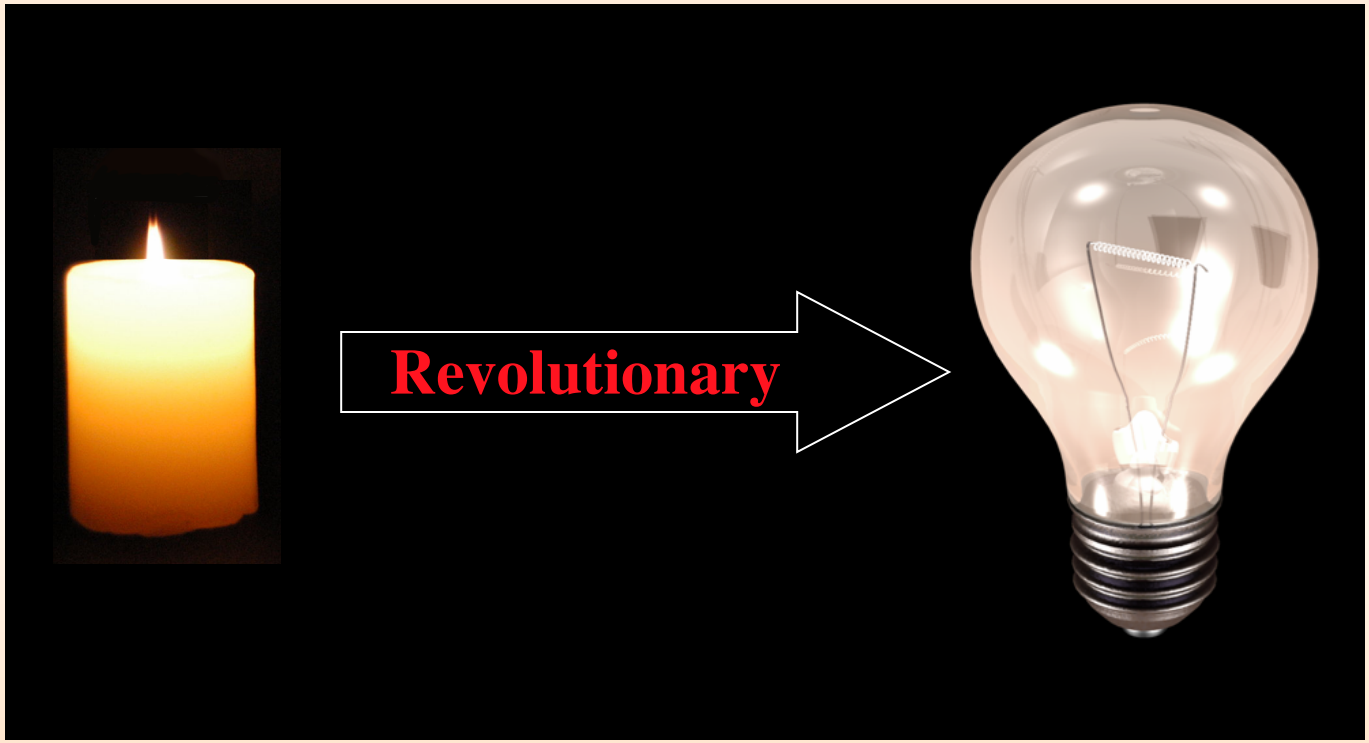
20th Century

- Reducing problems to their ultimate simplicity
- Atomic-scale characterization
- Elementary excitations
- Miniaturization

21st Century

- **Beyond the basic architecture of nature**
- Embracing complexity
- Atomic-scale control
- Emulating Nature
- Self-assembly

Light



Energy Crisis

Environment

Homeland Security