

Frontiers in Science

Levitation, Superconductivity, And The World's Largest Magnets

Dr. Gregory S. Boebinger
National High Magnetic Field Laboratory

At the National High Magnetic Field Laboratory (NHMFL) in Los Alamos, we develop the world's most powerful electromagnets, more than a million times stronger than the Earth's magnetic field, for use in basic research experiments. These electromagnets are powered by a 1.4 Billion-watt generator, the largest electrical generator in the United States, which delivers the energy equivalent of dozens of sticks of dynamite to the magnet during a magnet pulse.

The Frontiers in Science Public Lecture Series is in an effort to inform neighboring communities about the broad range of scientific and engineering research that is being done at the Laboratory. The series will highlight Laboratory science and will be presented by Laboratory scientists. To reach the broadest audience possible, each talk will be presented four times, once each in Santa Fe, Los Alamos, Espanola, and Taos.



Sponsored by the
Fellows of the Los Alamos
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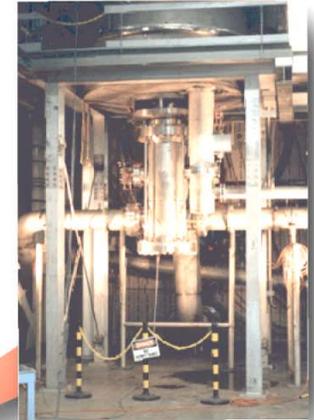
Los Ranchos de Albuquerque:
Thur, June 20, 2002
Taft Middle School



A new series of lectures in **Fall 2002**
Free Admission
For more information visit our web page
<http://stb.lanl.gov/fellows/fellows.html>



NATIONAL HIGH MAGNETIC FIELD LABORATORY



450,000 Gauss Hybrid Magnet

Florida State University



Los Alamos National Laboratory

1.4 Billion Watt Generator



High Magnetic Field Low Temperature Facility



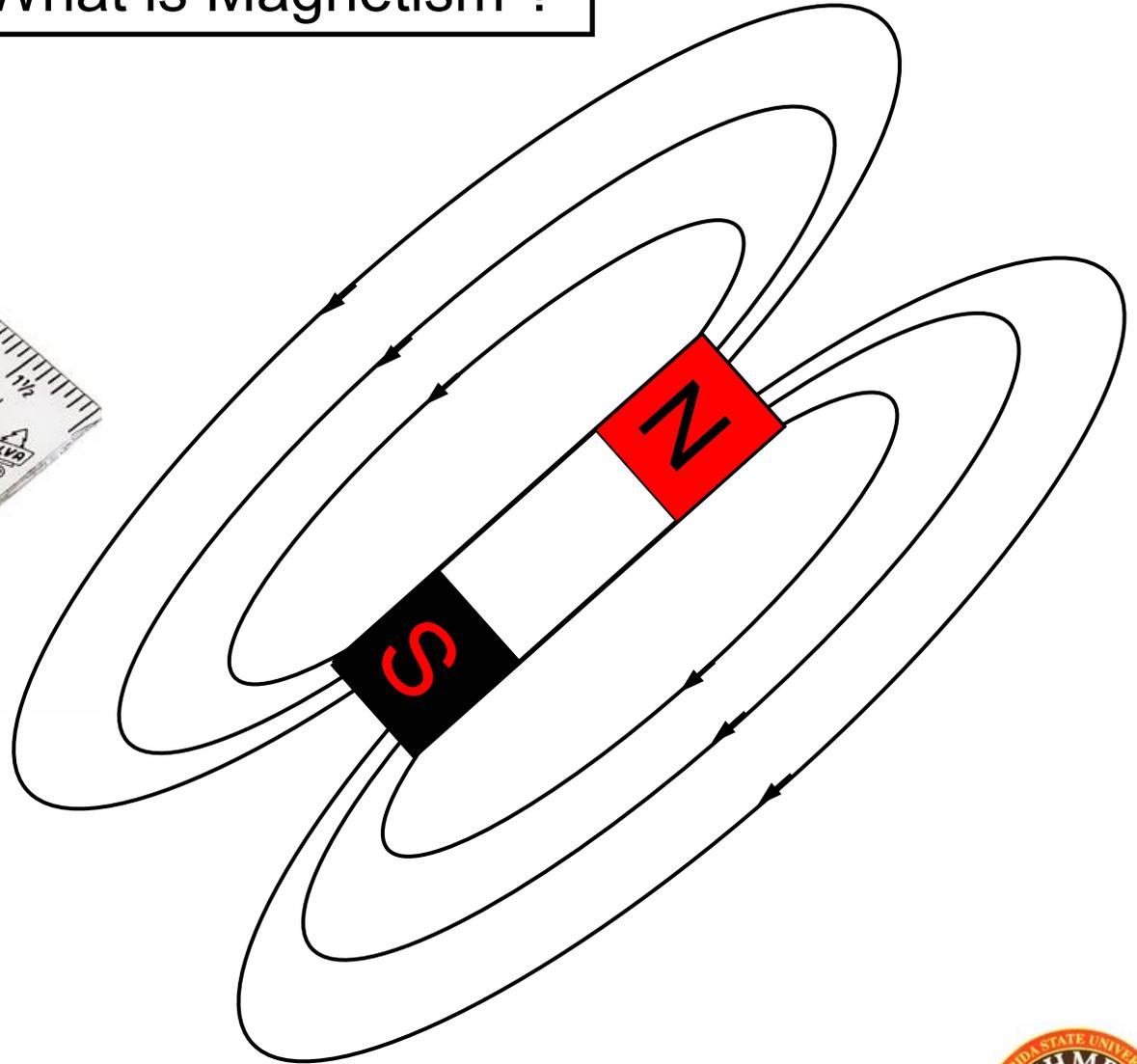
120,000 Gauss Magnetic Resonance Imaging (MRI) Magnet

University of Florida



600,000 Gauss Long-Pulse Magnet

What is Magnetism ?



National High Magnetic Field Laboratory



What is Magnetism ?

Magnetism and Electricity are completely intertwined.

Electrical current (moving electrical charge) creates magnetism.

Moving magnets create electrical current in nearby conductors.

What is Electro-Magnetism ?

Electromagnetism is one of the Four Fundamental Forces known in nature.

Strong Nuclear Force.....holds the nucleus together

Weak Nuclear Force.....controls radioactivity

Gravity.....keeps order in the galaxy...

.....serves to keep humans attached to the earth.

Electro-Magnetism.....

Why is Magnetism interesting to most people?

Almost nobody knows about the weak and strong nuclear forces.

We all know about gravity....but we can't do much with it.

Magnetism looks like magic....it's the only force we can play with.



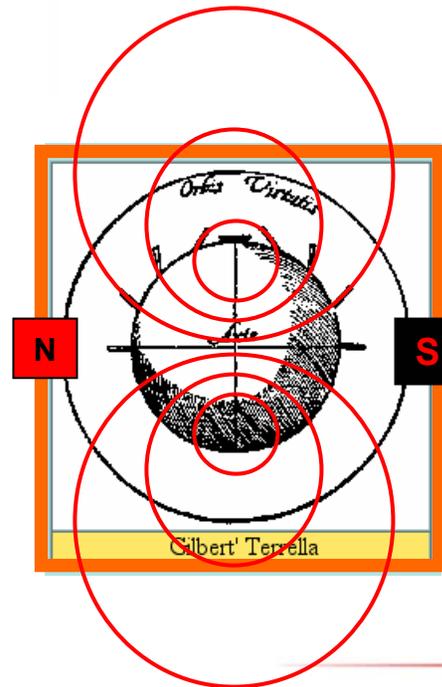
A Bit of the History of Magnetism

~2000 years ago Humans already know about natural lodestones
 1100's Chinese used lodestones as a navigational tool



1200's Peter Peregrinus discovered...
 ...that magnets have two opposing ends.
 ...that lodestone can magnetize a needle
birth of the modern compass

c. 1600 William Gilbert discovered...
 ...that the earth is magnetic.
North and South Poles



William Gilbert



What is Magnetism ?

Magnetism and Electricity are completely intertwined.

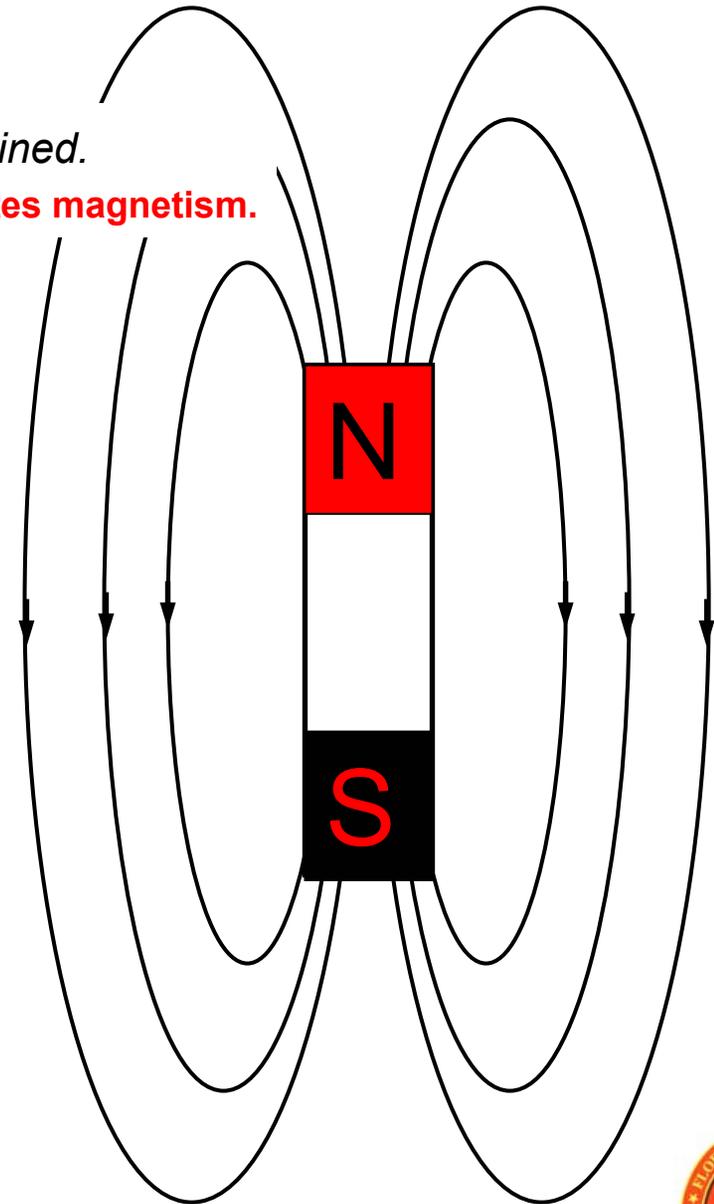
Electrical current (moving electrical charge) creates magnetism.

A Bit of the History of Magnetism



Andre-Marie Ampere

1820-27 Discovered that Electricity in Motion
can produce Magnetism



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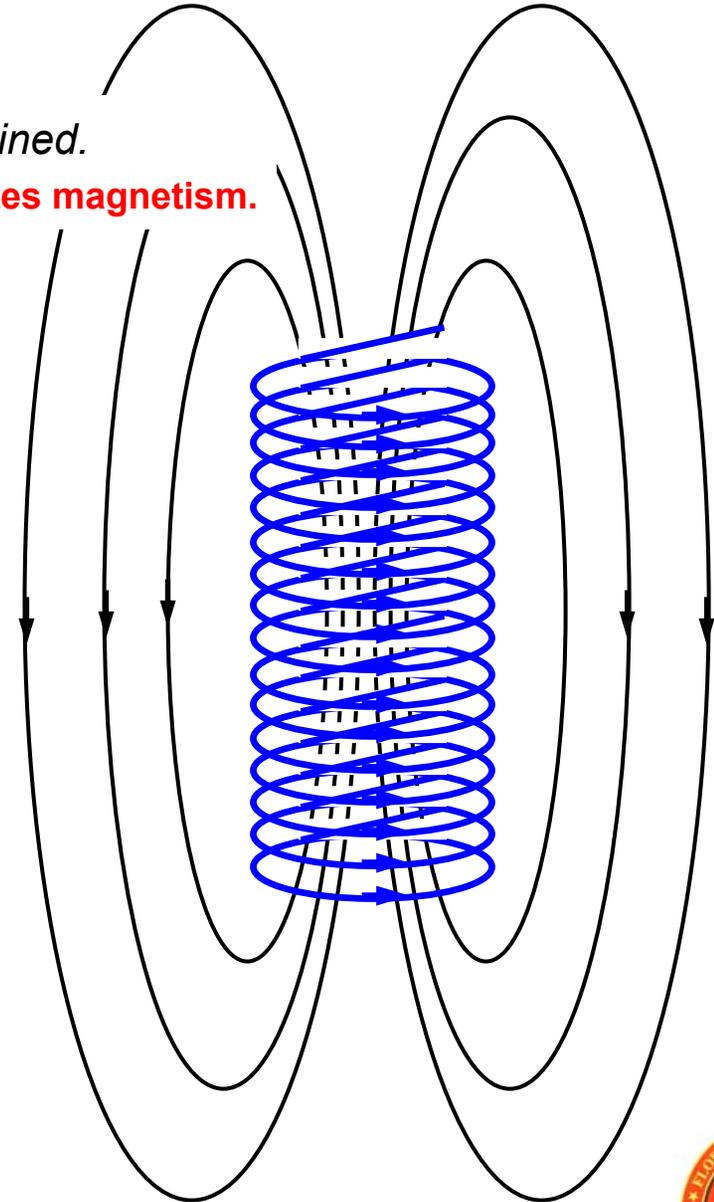
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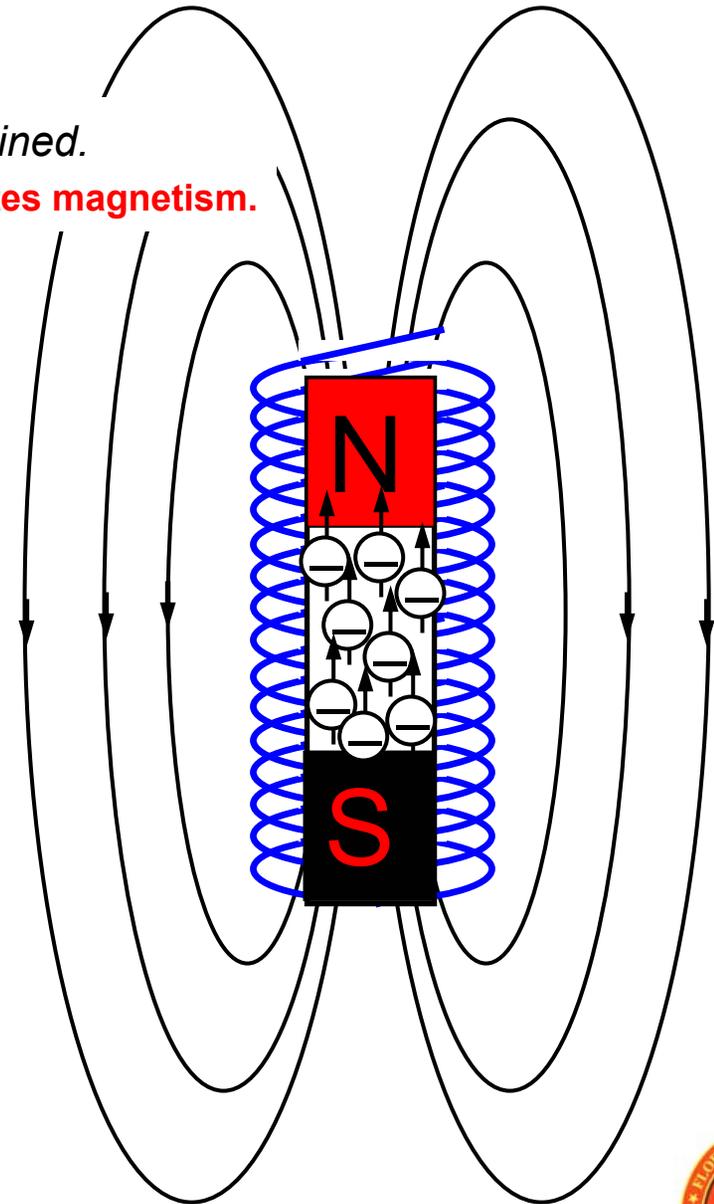
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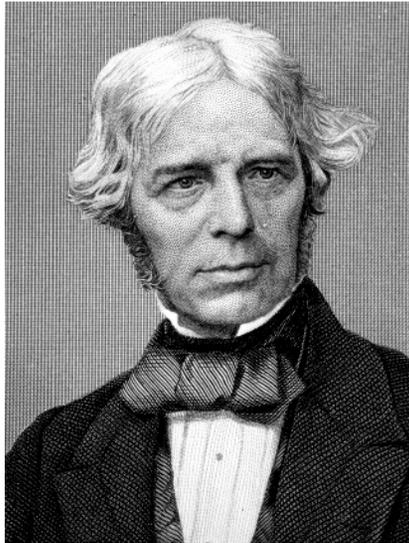
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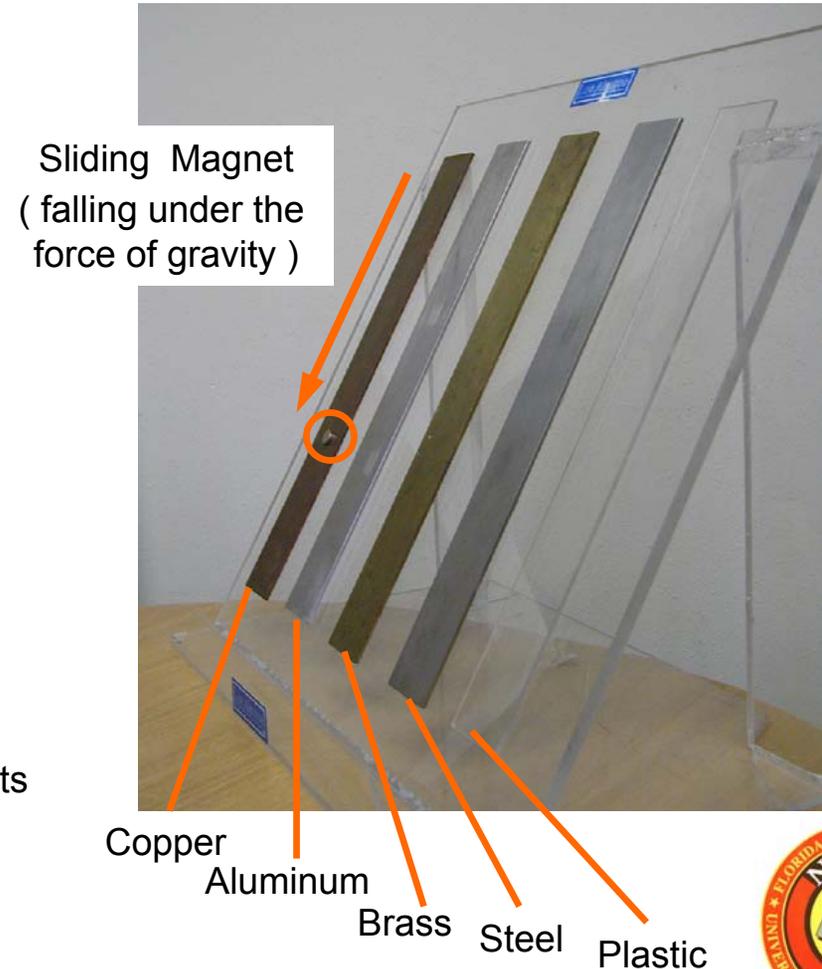
Moving magnets create electrical current in nearby conductors.

A Bit of the History of Magnetism



Michael Faraday

1821-31 Discovered that the Motion of Magnets can produce Electricity.

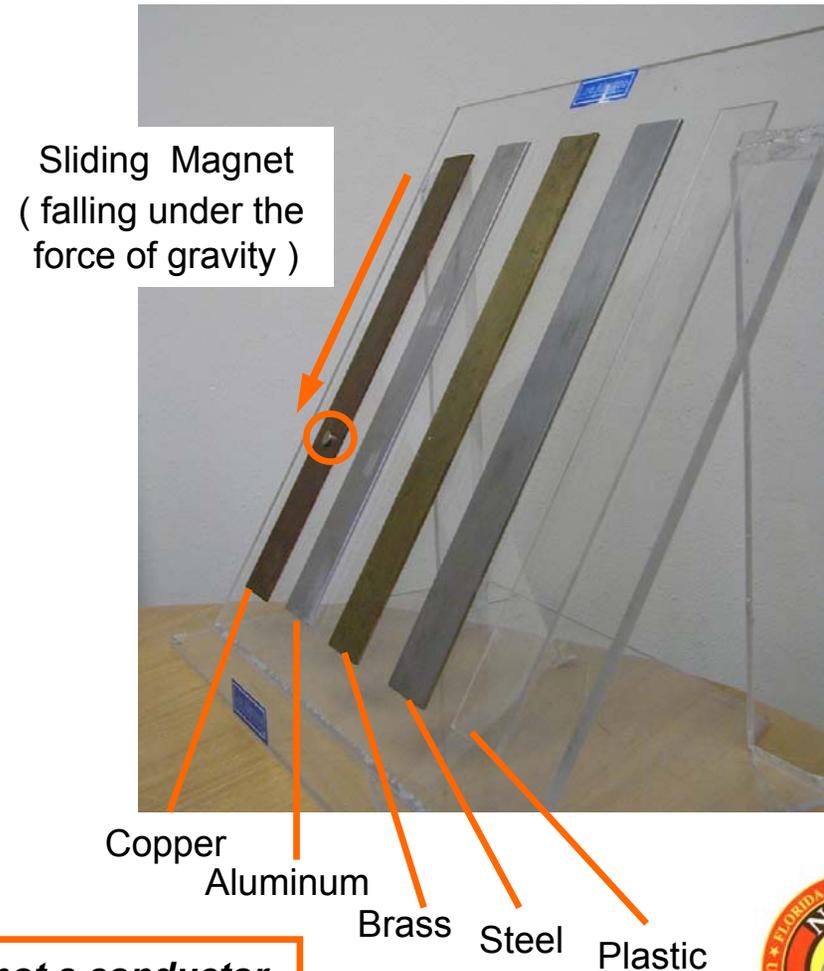
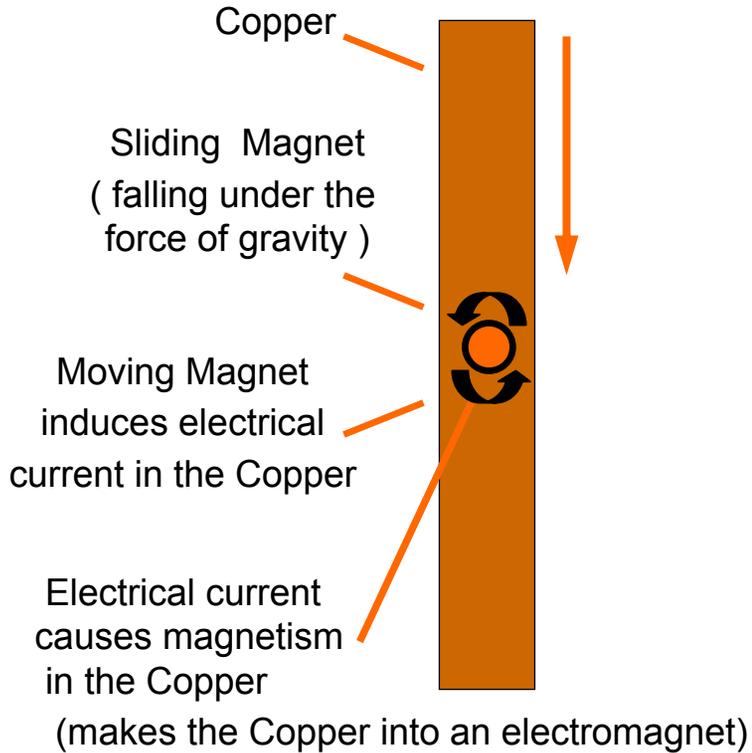


What is Magnetism ?

Magnetism and Electricity are completely intertwined.

Electrical current (moving electrical charge) creates magnetism.

Moving magnets create electrical current in nearby conductors.



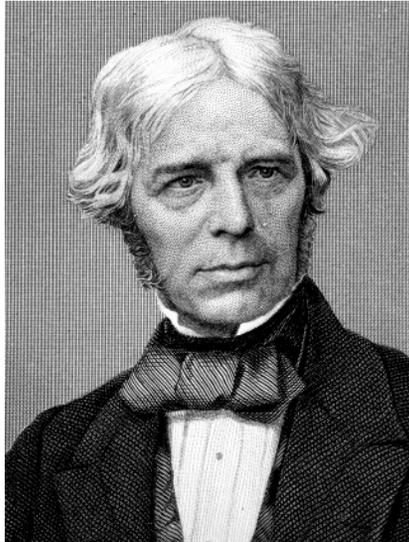
***If the magnet does not move,
there is no attraction.***

***If the material is not a conductor,
there is no attraction.***



Magnetism and Electricity are completely intertwined.

A Bit of the History of Magnetism

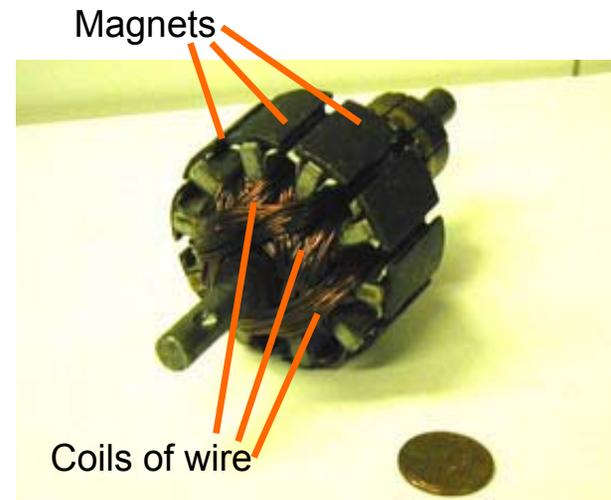


Michael Faraday

1821-31 Discovered that the Motion of Magnets can produce Electricity.

Discovered that Electricity and Magnets together can produce Motion.

....from which were developed
electrical generators and
electrical motors...
*....and the industrial revolution
was on....*



Magnetism and Electricity are completely intertwined.

....from which was developed
electrical generators and
electrical motors...

....and the industrial revolution
was on....



From Motion to Electricity.....GENERATOR

Generator (inside Hoover Dam)

Copper wire
(Power Lines)

Lightbulb
(Your House)



Motion provided by
hand cranking
(falling water at
Hoover Dam)

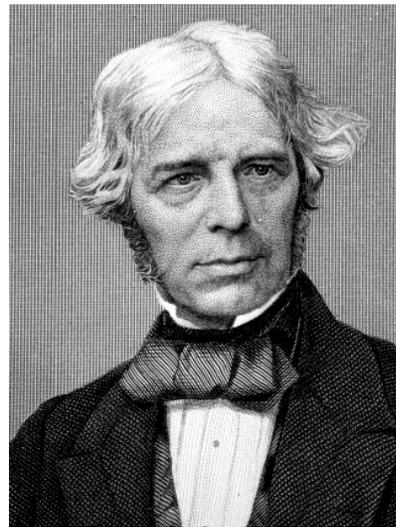
From Electricity to Motion.....MOTOR



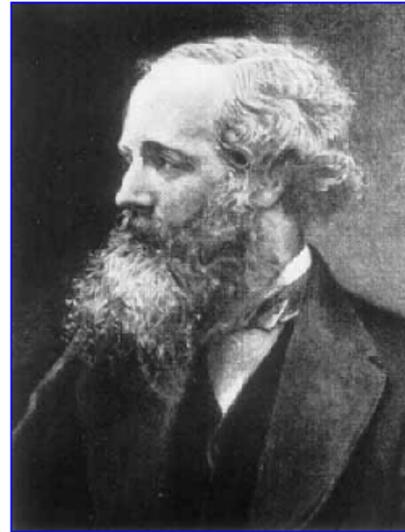
A Bit of the History of Magnetism



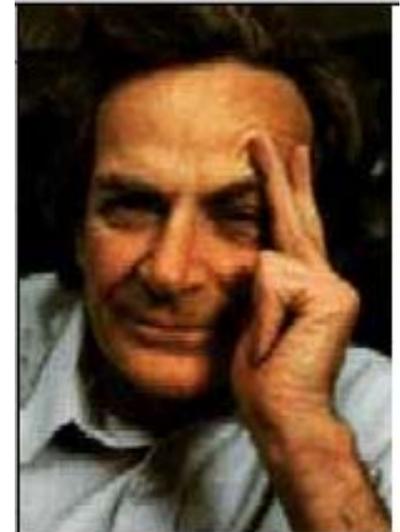
Andre-Marie Ampere



Michael Faraday



James Clerk Maxwell



Richard Feynmann

1855-56 Wrote a set of four equations that unify Electricity, Magnetism and Light

...and radio waves, microwaves, infrared waves, ultraviolet light, X-rays and gamma radiation...

1950 Developed Quantum Electrodynamics
The electromagnetic interaction is caused by electrons exchanging a particle of light (a photon)

1965 Nobel Prize in Physics

Driving Force, the Natural Magic of Magnets

by James D. Livingston

Harvard University Press, 1996

ISBN 0-674-21644-X

Hidden Attraction, the Mystery and History of Magnetism

by Gerrit L. Verschuur

Oxford University Press, 1993

ISBN 0-19-506488-7

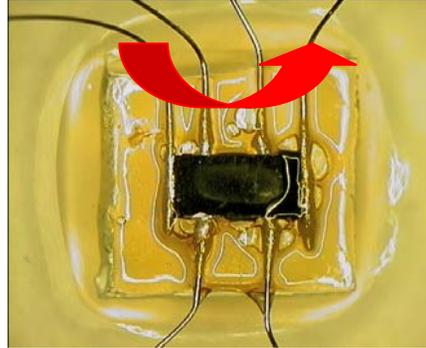


A Bit of the History of Superconductivity

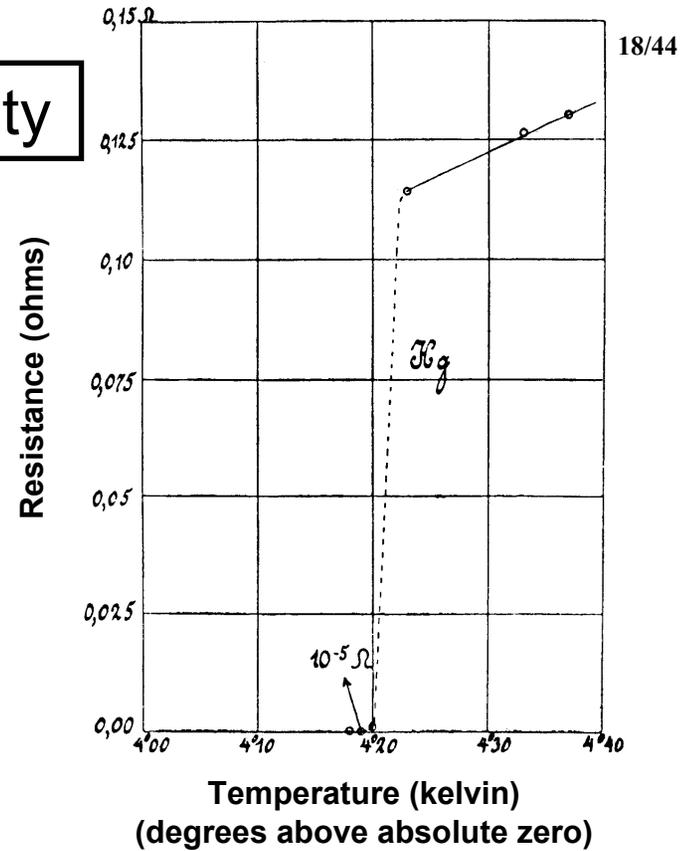


Heike Kamerlingh Onnes

Put electricity through the sample

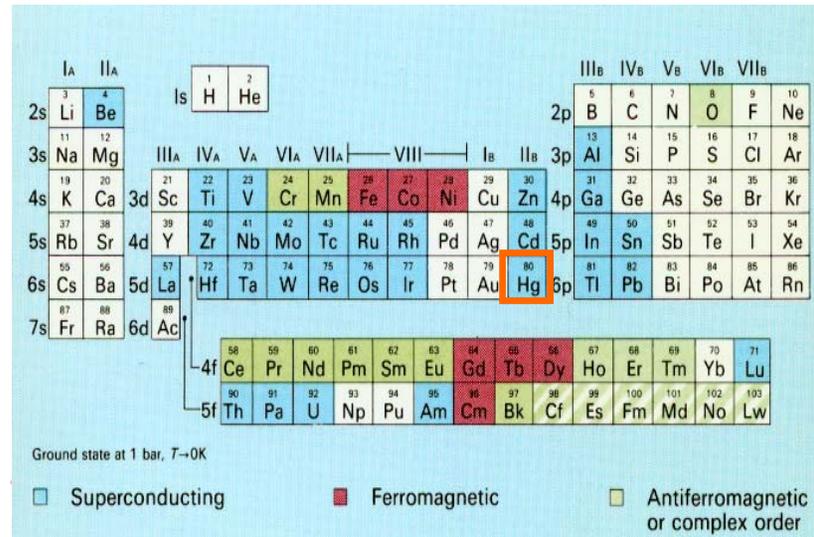


Measure the voltage...
...the energy lost by the electricity in the sample
(heats up the sample)



1911 Discovered superconductivity, the fact that electrical resistance drops suddenly to zero in some materials

1913 Nobel Prize in Physics



Pre-cool YBCO

Resistance

A Bit of the History of Superconductivity



Heike Kamerlingh Onnes

1911 Discovered superconductivity,
the fact that electrical resistance
drops suddenly to zero in some materials

1913 Nobel Prize in Physics

...and then came 1987...



John Bardeen

Leon Cooper

Robert Schrieffer

1957 Developed the theory of superconductivity,
which explained all known superconductors....
...and thus became the widely accepted theory....

1972 Nobel Prize in Physics

...and the discovery of high-temperature superconductors...



Why Magnetic Field Research ?

Magnetic Materials plus Electromagnets

Do you use a...watch? (*those hands don't go 'round powered by springs anymore !*)

automobile? (generator, power windows, power locks)

computer ? (disk drive motor, hard drive, read/write mechanism for hard drive)

stereo? (CD motor, cassette motors, speakers, headphones, cassette tape,
read/write mechanism for cassette tape)

any manufactured goods? (robotic assembly lines)

MagneForce Shoes ! According to a brochure describing the benefits of MagneForce shoes:

"Magnetism represents one of the most basic powers in the universe.

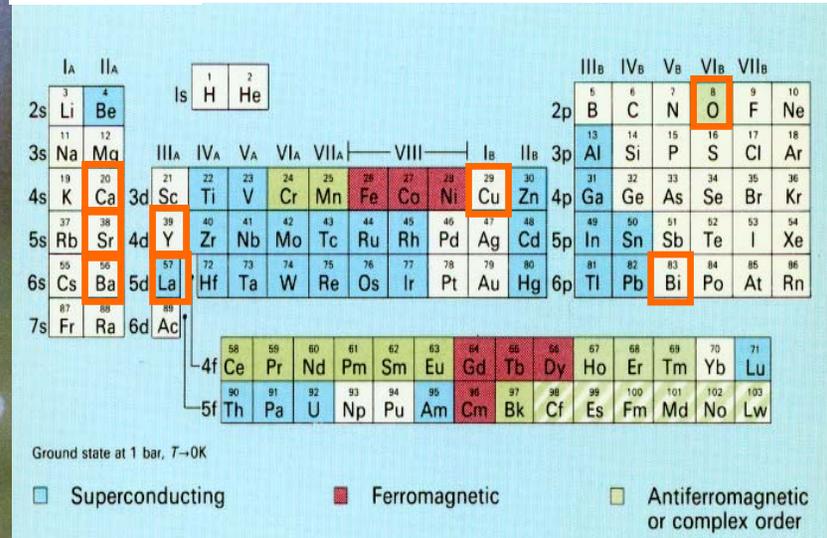
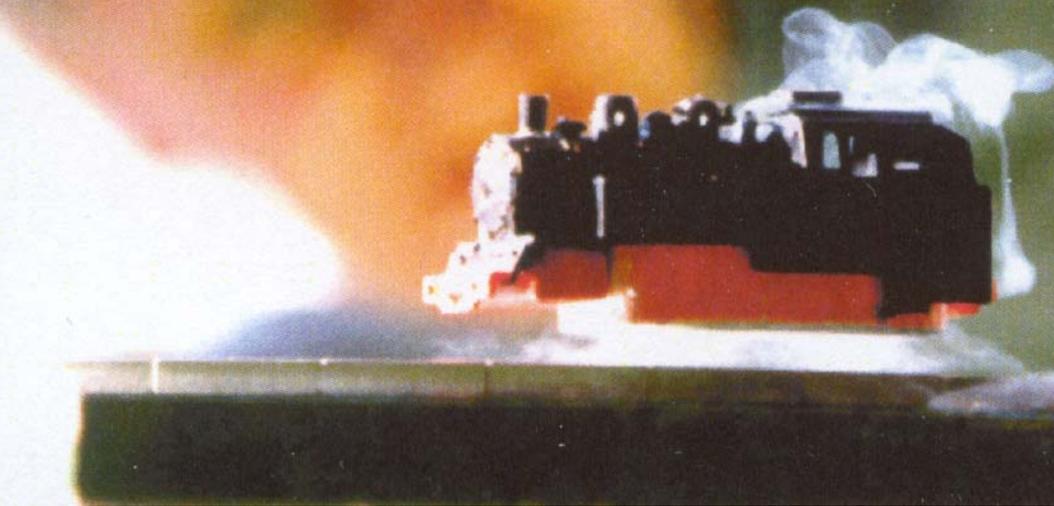
This force keeps order in the galaxy,
allowing the stars and planets to spin at significant velocities...

At the earth's surface, the magnetic field is relatively weak,

but serves to keep humans attached to the earth. Without it we would spin off into space."

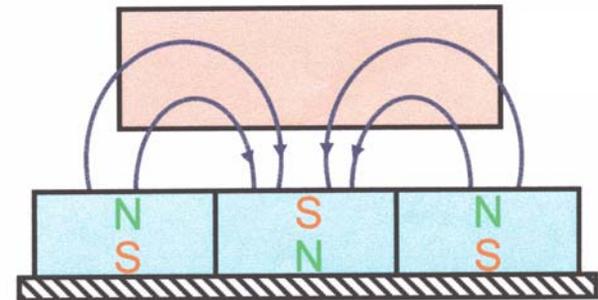


A Bit of the History of Magnetism and Superconductivity



YBaCuO LaSrCuO BiBaCaCuO

High-temperature Superconductor



Strong Permanent Magnets

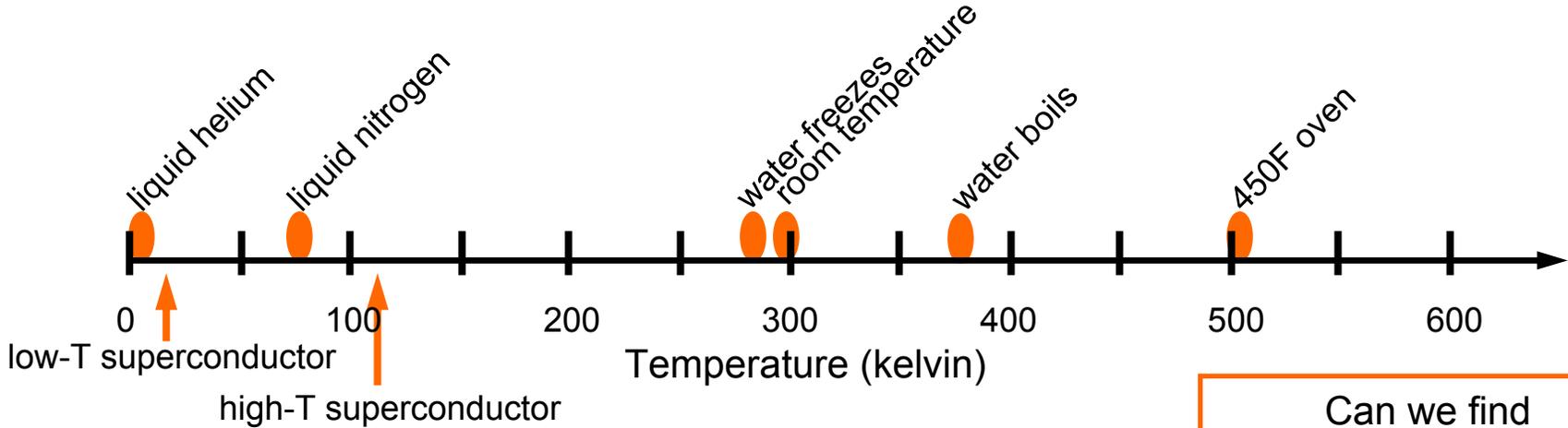
IFW
Institut für
Festkörper- und
Werkstofforschung
Dresden

Video

Demonstration

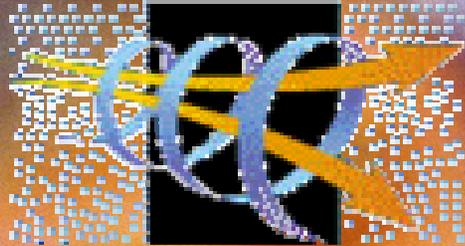


Why call this a "high-temperature" superconductor ?

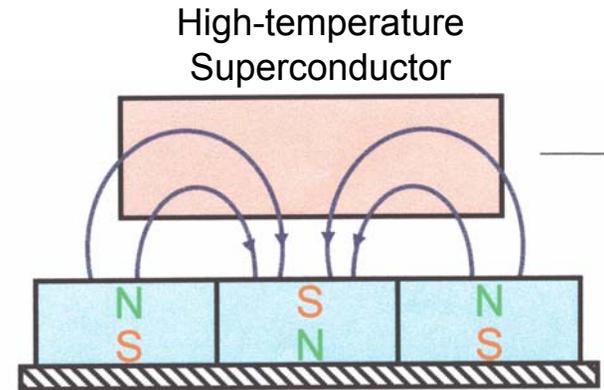


Can we find a room-temperature superconductor ?

Can we find technological applications for the high-temperature superconductors ?



Superconducting Technology Center

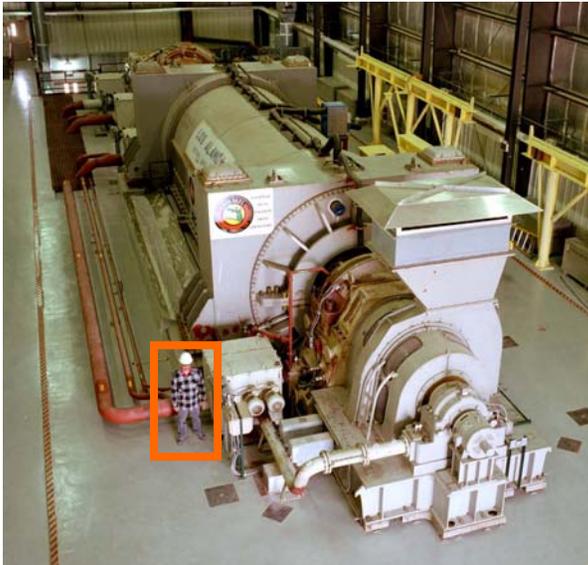


NHMFL Pulsed Magnet Facility in Los Alamos



1.4 Gigawatt Generator Building

Long-Pulse Magnet Building



www.lanl.gov/mst/nhmfl



NHMFL Pulsed Magnet Facility in Los Alamos



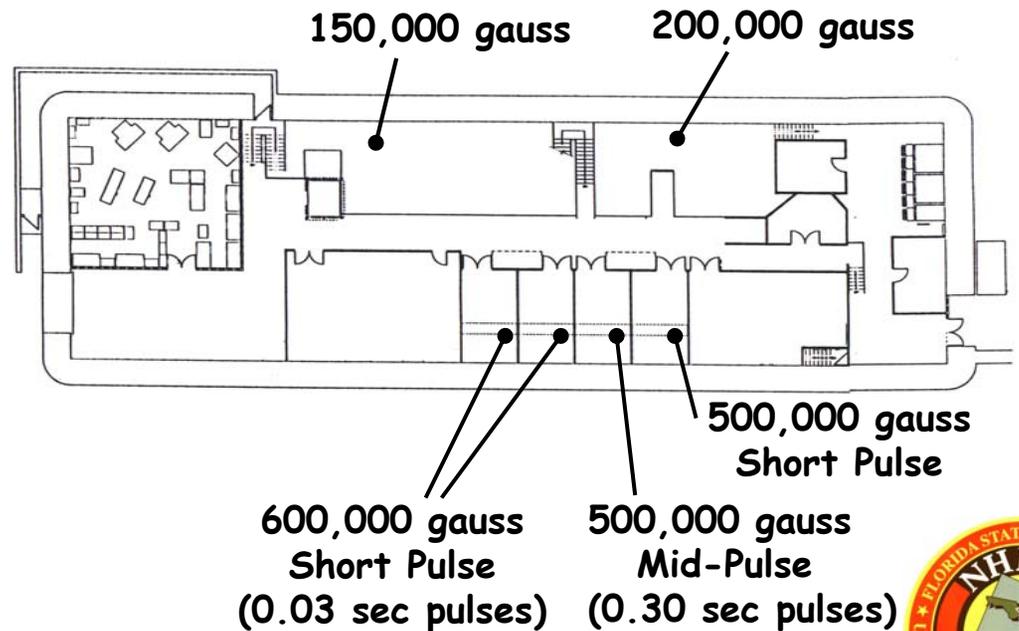
New Experimental Hall

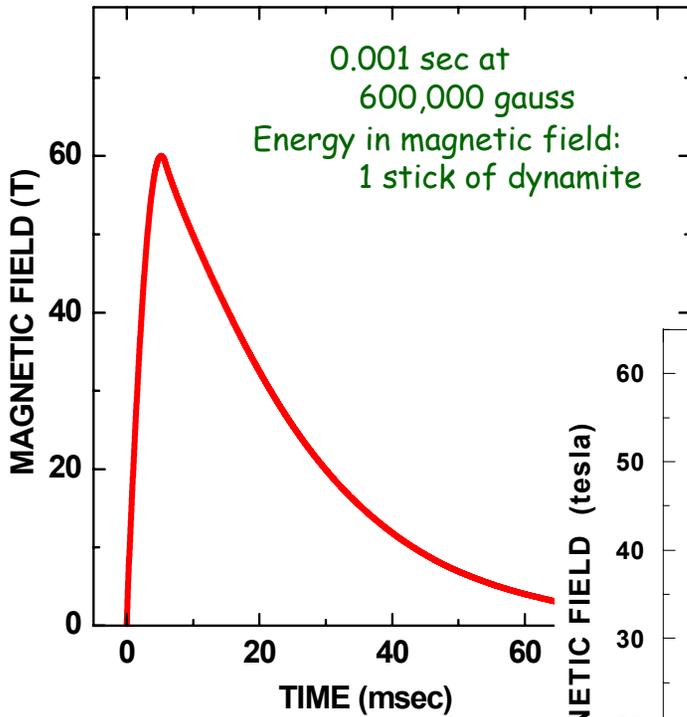
**Pulsed Magnets
powered by a
1.4 Million Joule Capacitor Bank
0.03 to 0.30 second-long pulses**



www.lanl.gov/mst/nhmfl

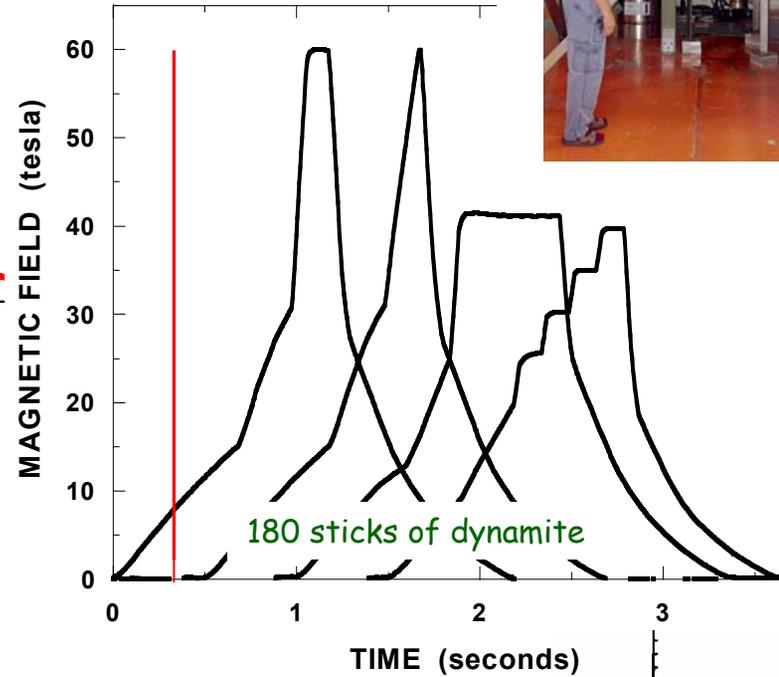
Superconducting DC Magnets





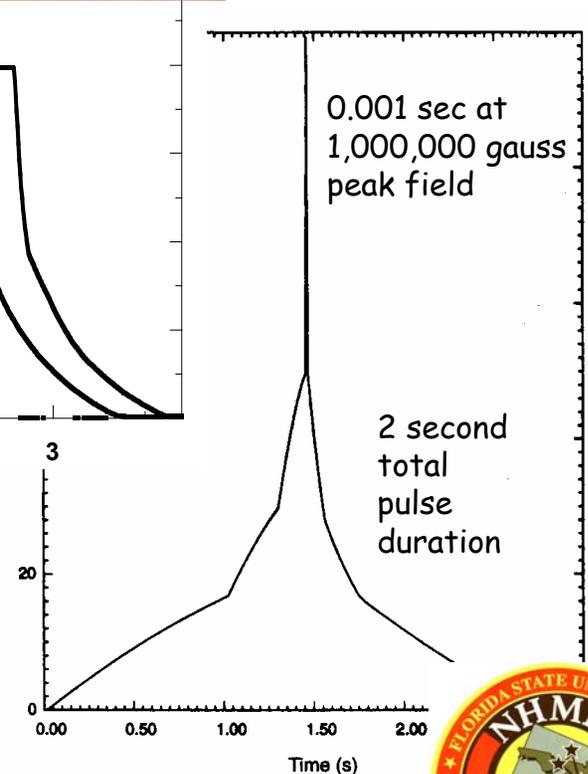
0.100 sec at 600,000 gauss peak field

Controlled Pulse Profiles



0.001 sec at 1,000,000 gauss peak field

2 second total pulse duration



1,000,000 gauss magnet
250 sticks of dynamite



www.lanl.gov/mst/nhmfl

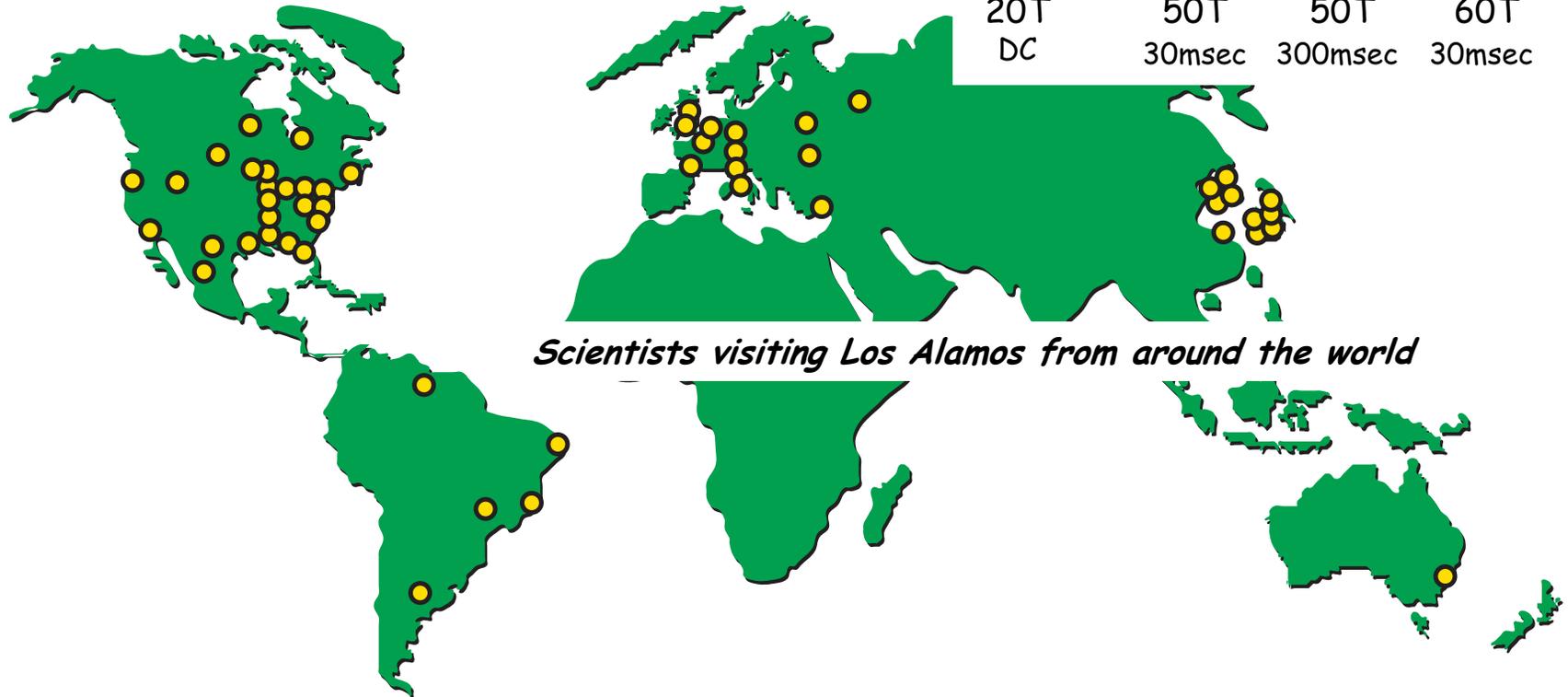
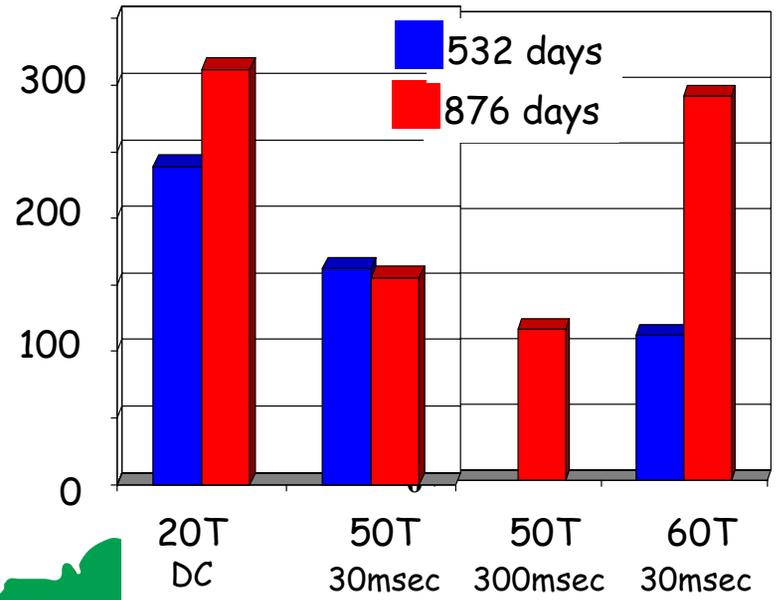


The NHMFL/LANL User Program

www.lanl.gov/mst/nhmfl



Magnet Days in 1998 and 2001

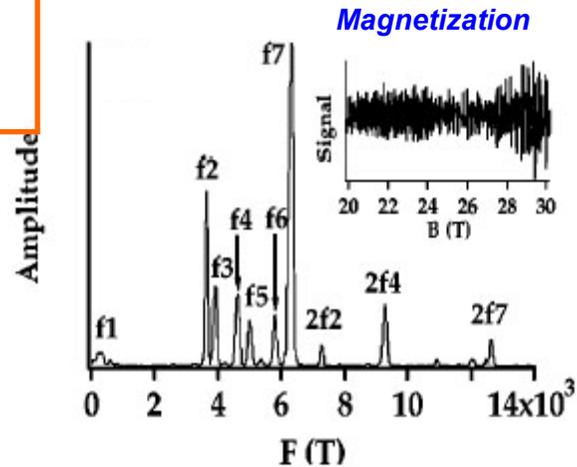


Scientists visiting Los Alamos from around the world

Science in 600,000 gauss

at the National High Magnetic Field Laboratory

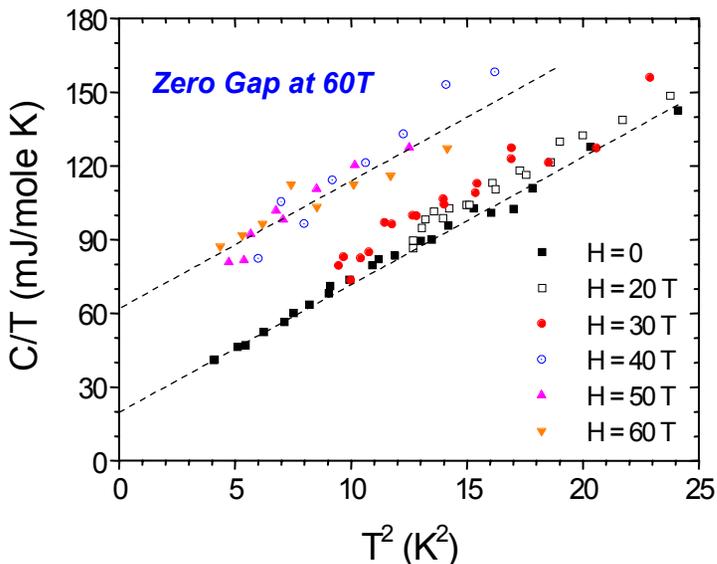
www.lanl.gov/mst/nhmf



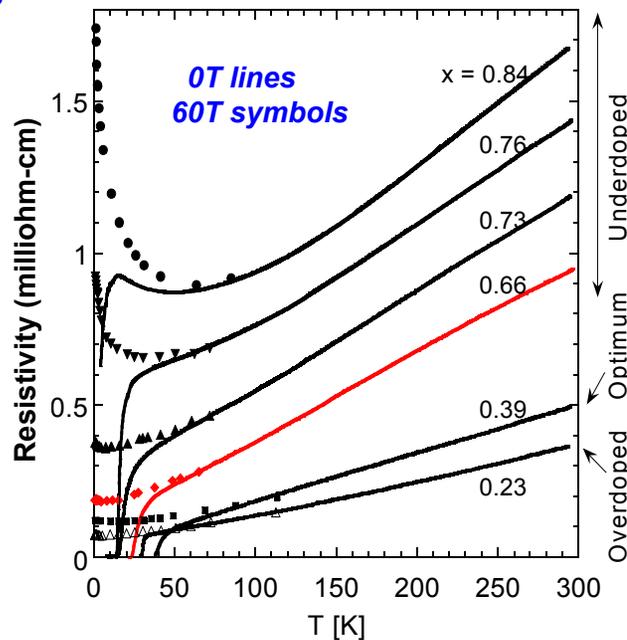
Fermi Surfaces of Rare Earth Alloys

Goodrich, et al, Phys Rev Lett 82 (1999) 3669
Alver, et al, Phys Rev B (RC) 64 (2001) 180402

Six fully-multiplexed magnet cells host 150-200 visiting scientists a year, 20% of whom travel from overseas to use our unique capabilities



Specific Heat in a Kondo Insulator
Jaime, et al, Nature 405 (2000) 160



Transport in the High-Tc Superconductors

Ono, et al, Phys Rev Lett 85 (2000) 638
Morozov, et al, Phys Rev Lett 84 (2000) 1784

Field-induced Landau-gap Organic Insulator

Nam, et al, Phys Rev Lett 87 (2001) 117001

Other Experimental Techniques include...

- Hall effect
- Penetration Depth
- Ultrasonic Attenuation
- Photoluminescence
- Picosecond Time-Resolved Photoluminescence
- Gigahertz spectroscopy
- Terahertz spectroscopy

