

Modern Topics in Physics

A brief overview of Carbon Nanostructures,
Superconductivity, Spin and Experimental Weapons

Modern Topics in Physics

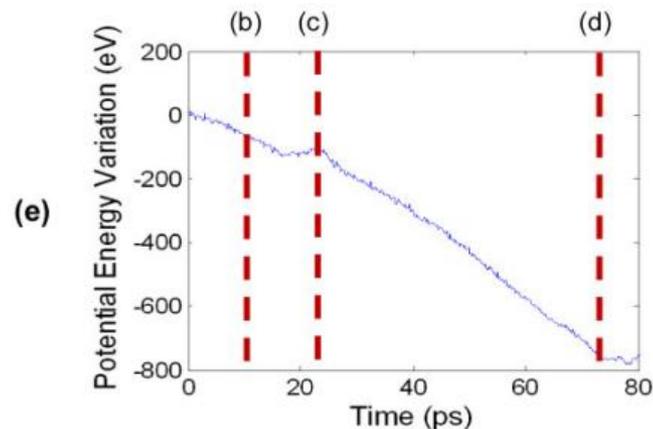
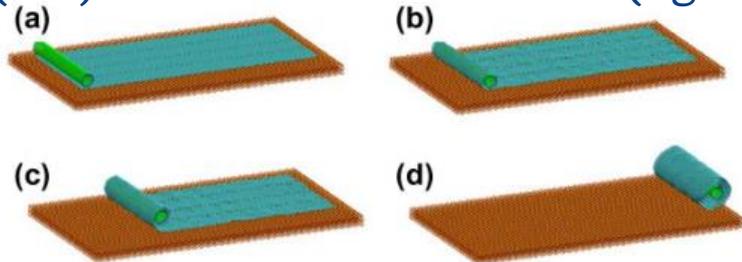
Carbon Nanostructures

Modern Topics: Carbon Nanostructures

Graphene: Surprisingly simple

First discovered with the invention of radio crystallography.

2010 Nobel prize awarded to Andre Geim (left) and Konstantin Novoselov (right).



In 2008 Graphene was worth \$100 000 000 cm²

Mechanical exfoliation

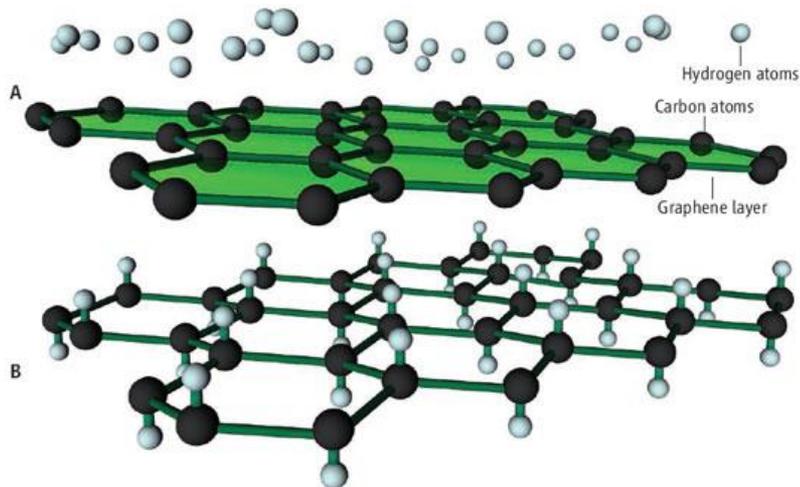
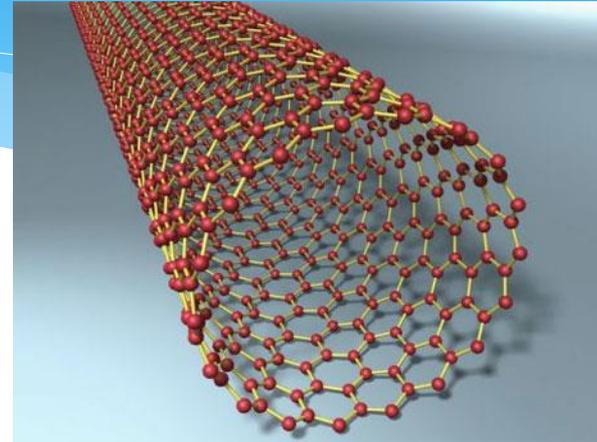
Growth on metal substrates

Modern Topics: Carbon Nanostructures

Graphane: Out with the old

Created through introduction of hydrogen to a graphene sheet.

The storage of hydrogen could make graphene incredibly useful in the future.



The addition of hydrogen results in an excellent insulator.

Graphene in its many forms could replace the elements currently in use in electronics.

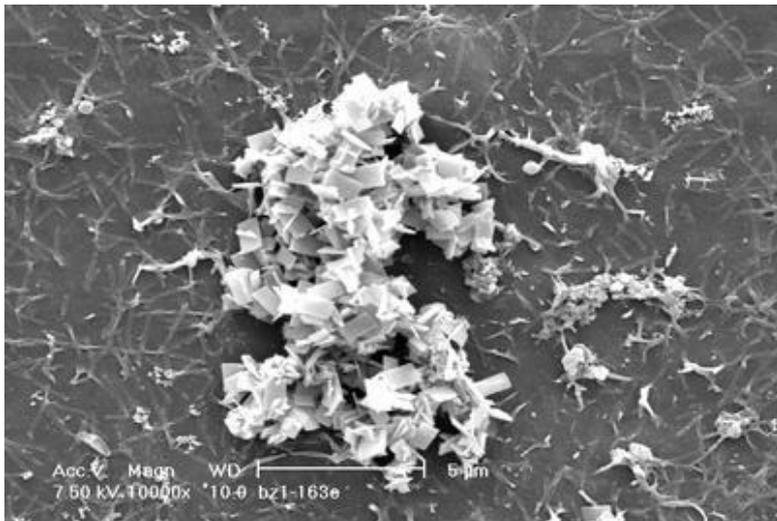
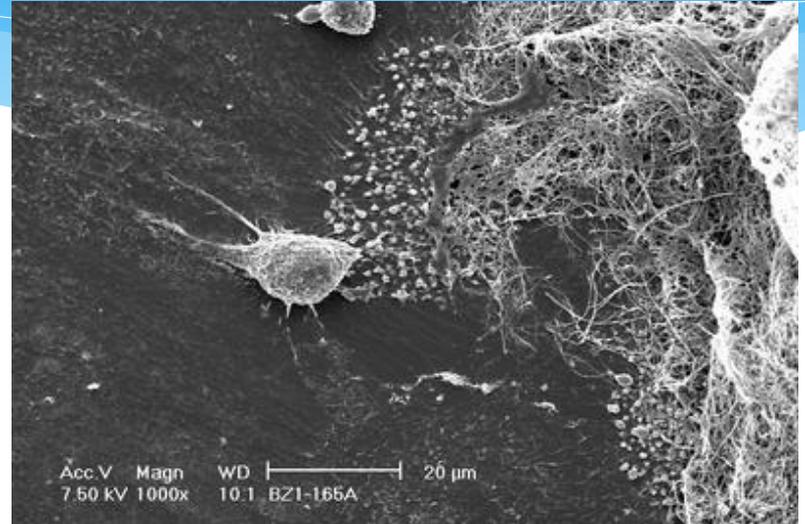
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Medicine:

Have been found to aid in the healing of bone fractures and breaks.

CNT's possess excellent biocompatibility.

The immune response of the body to CNT's has yet to be fully studied.



Use of etched nanopatterns upon the growth substrate to cause stem cells differentiate.

Could improve the lifetime of bone replacements, joints would benefit in particular.

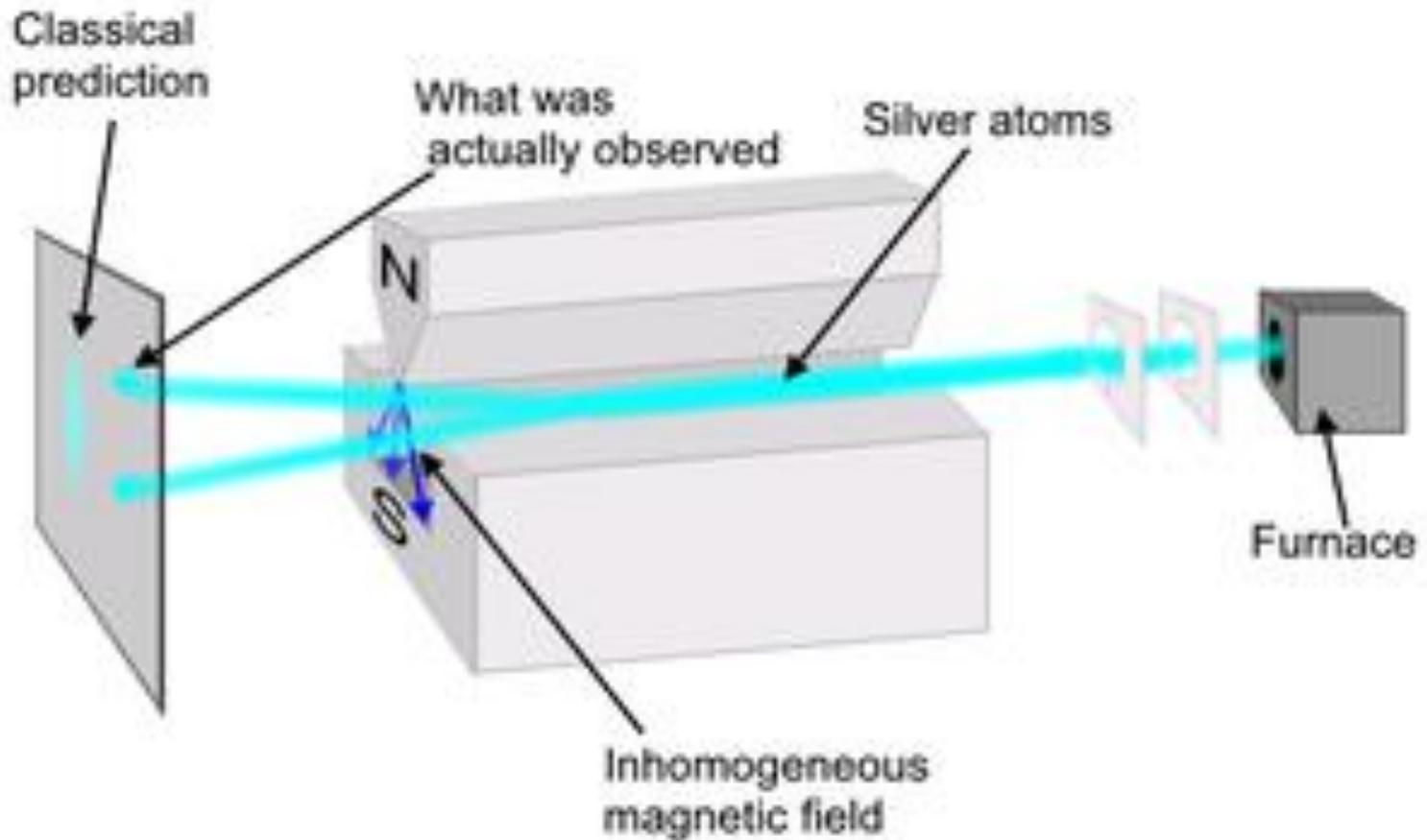
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Spin

Bohr's atomic theory (3 rules)

- * 1913 the Bohr model of the atom replaced Rutherford's model.
- * Electrons in atoms orbit the nucleus.
- * Electrons are in stationary orbits .
- * Energy levels are quantised.
- * $L = n\hbar$.

Stern & Gerlach experiment

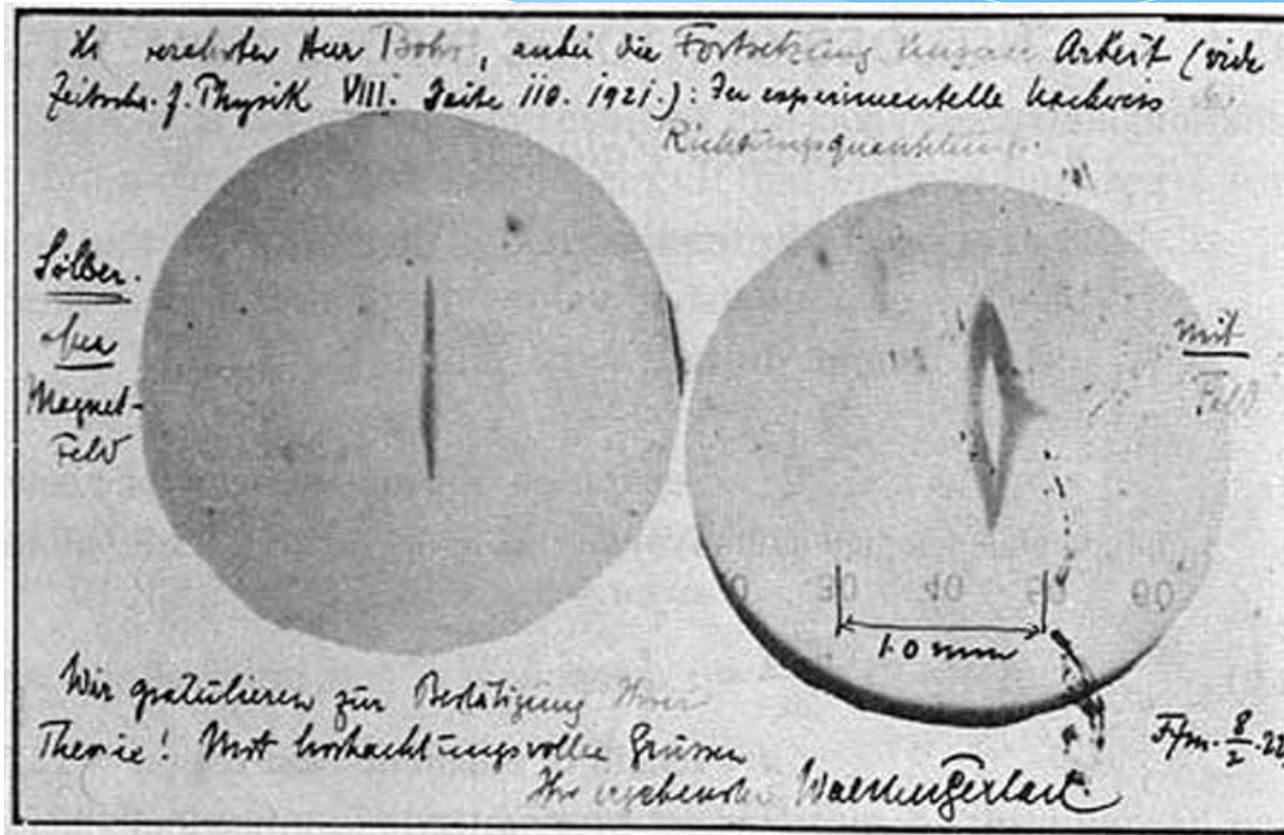


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The cigar story



Ceci n'est pas une pipe.



Gerlach's postcard, dated 8 February 1922, to Niels Bohr. It shows a photograph of the beam splitting, with the message, in translation: "Attached [is] the experimental proof of directional quantization. We congratulate [you] on the confirmation of your theory." (Physics Today December 2003)

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Applications of spin

- * Scientists used similar techniques to prove nuclei is similar to the electron
- * 1930 Isidor Rabi
- * Norman F Ramsey

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MRI



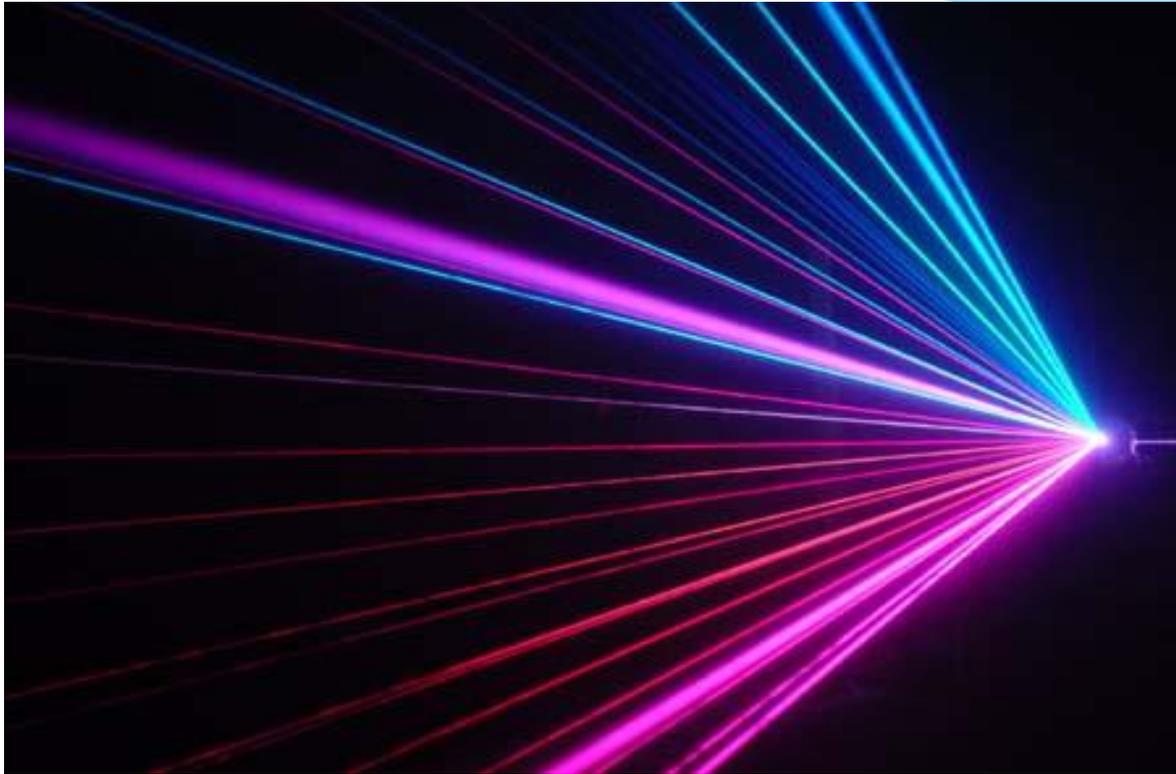
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Atomic clocks



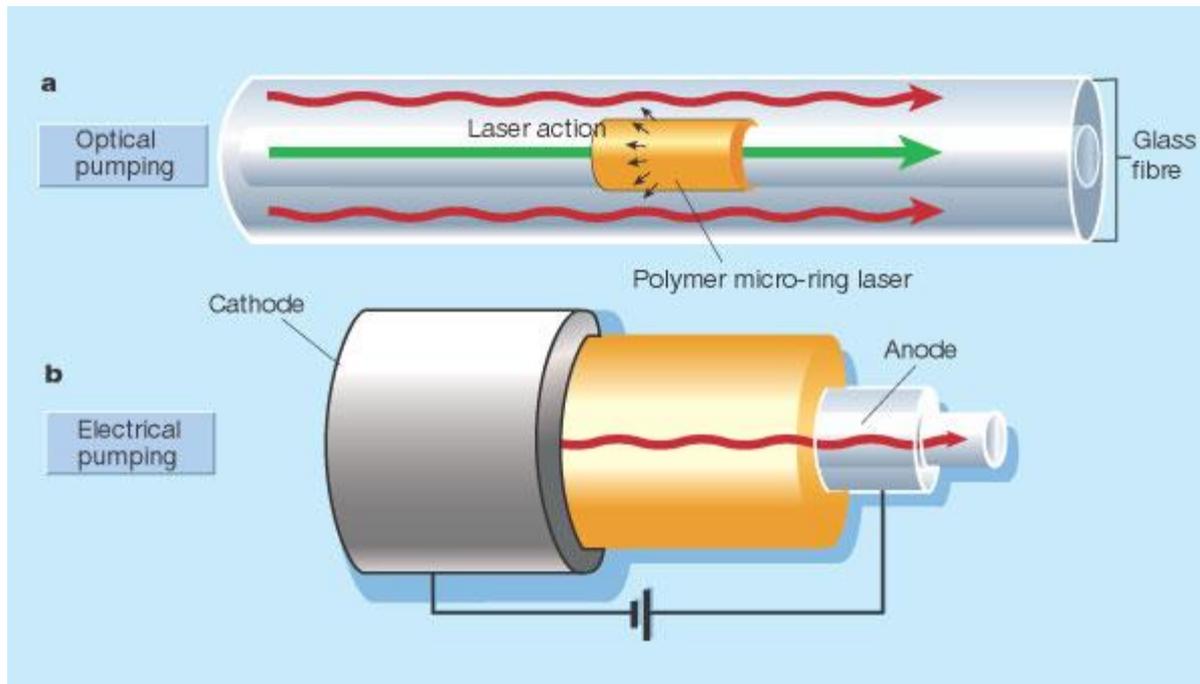
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Laser



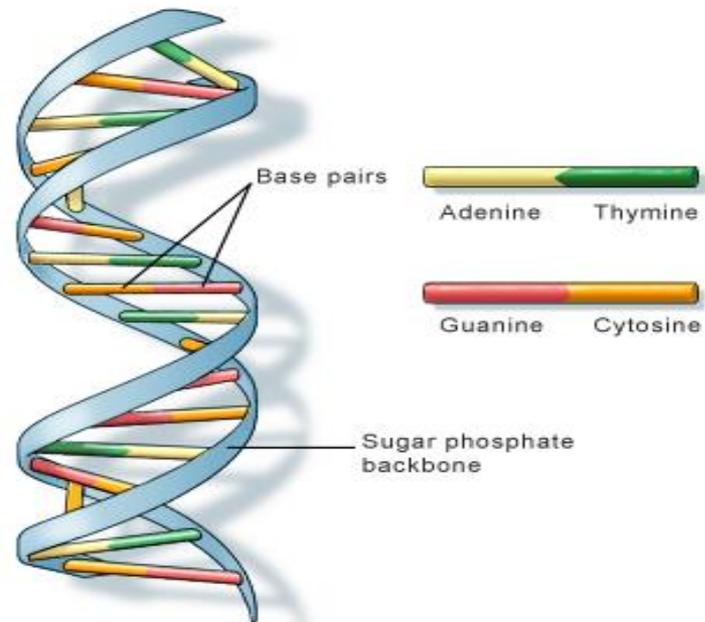
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Optical pumping



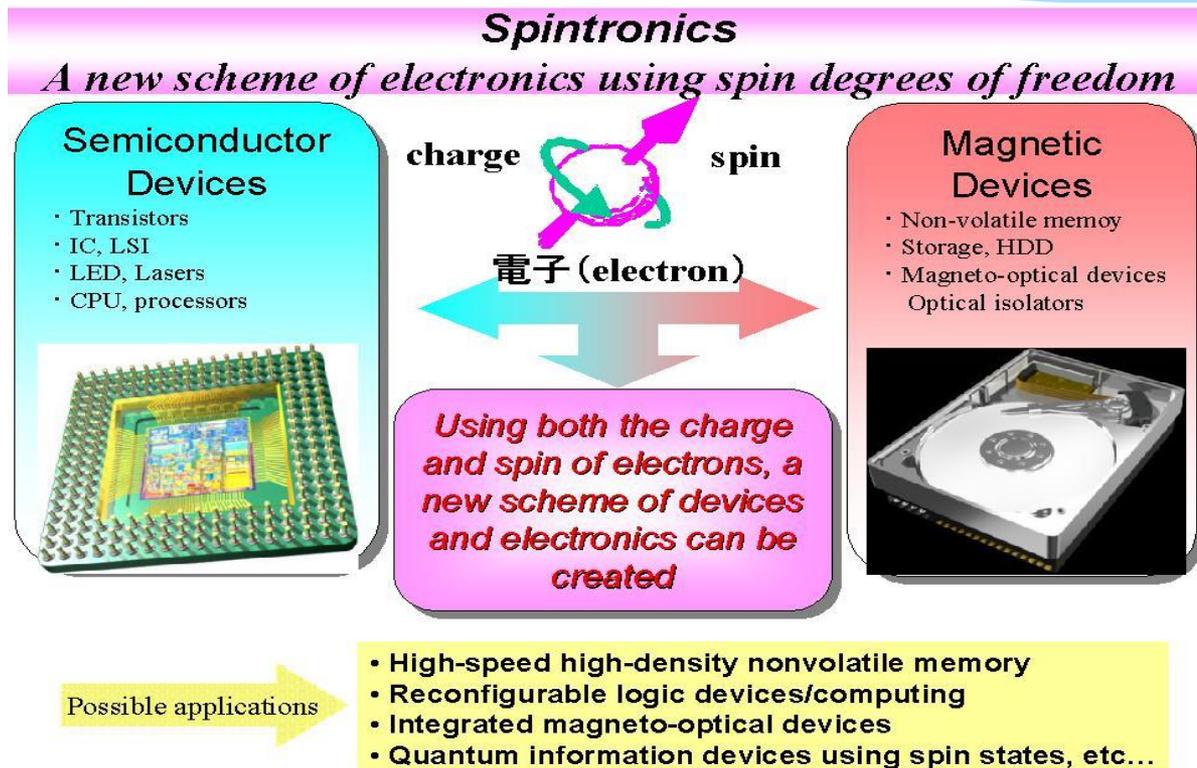
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DNA base pairs



U.S. National Library of Medicine

Spintronics



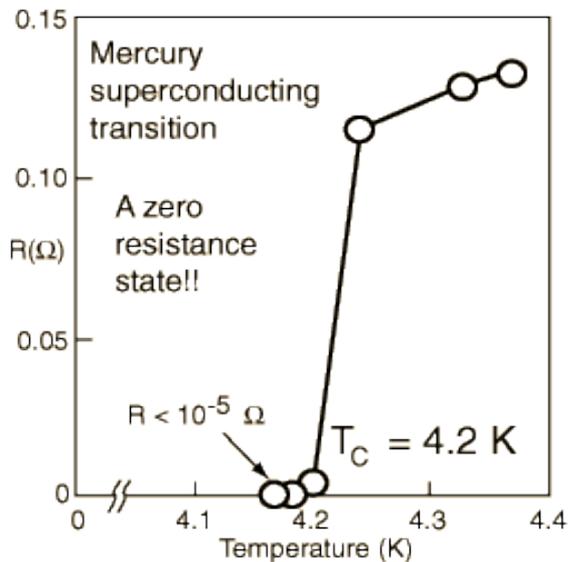
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Superconductivity

Modern Topics: Superconductivity

The discovery of Superconductivity

- * Discovered in 1911 by Heike Kamerlingh Onnes
- * Pure solid Mercury cooled to 4.2K was shown to have a massive drop in resistance



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The Theory of Superconductivity

- * Caused by cooling a material
- * Electrons form “Cooper Pairs”
- * Allows electrical charge to pass through “effortlessly” (no large energy dissipation)



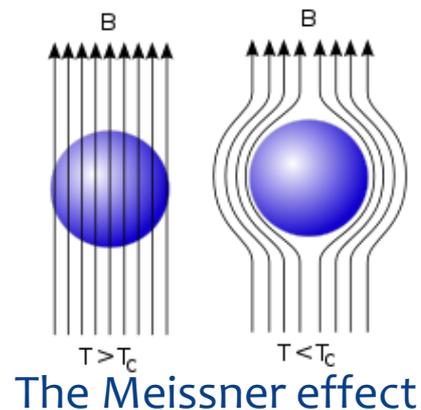
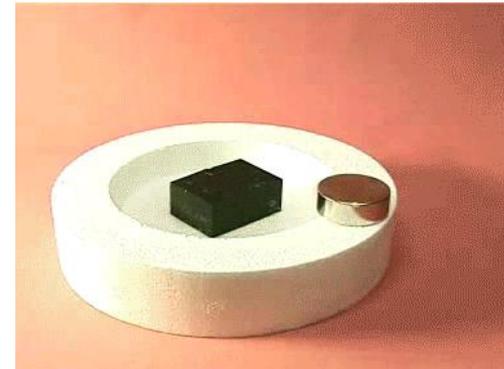
Animation of a Cooper pair
within a lattice

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The Characteristics of Superconductors

* 4 Main Characteristics of superconductors

- 1. Zero electrical DC resistance
- 2. Superconducting Phase Transition
- 3. Meissner effect
- 4. London moment



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The Applications of Superconductivity

- * Transportation in the form of “Maglev” trains
- * Can be used for medical purposes such as in a MRI scanner
- * Also has military applications such as in Railguns

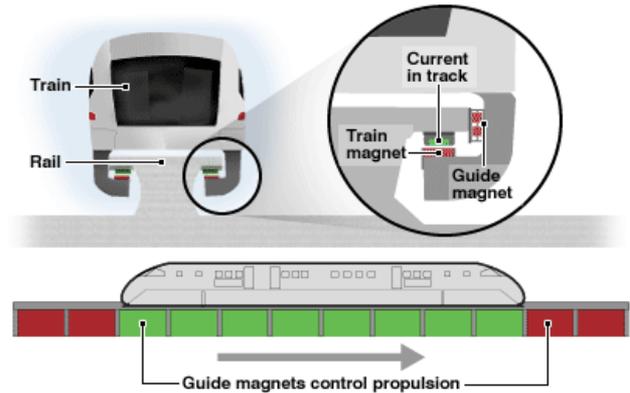


Diagram of a Maglev train

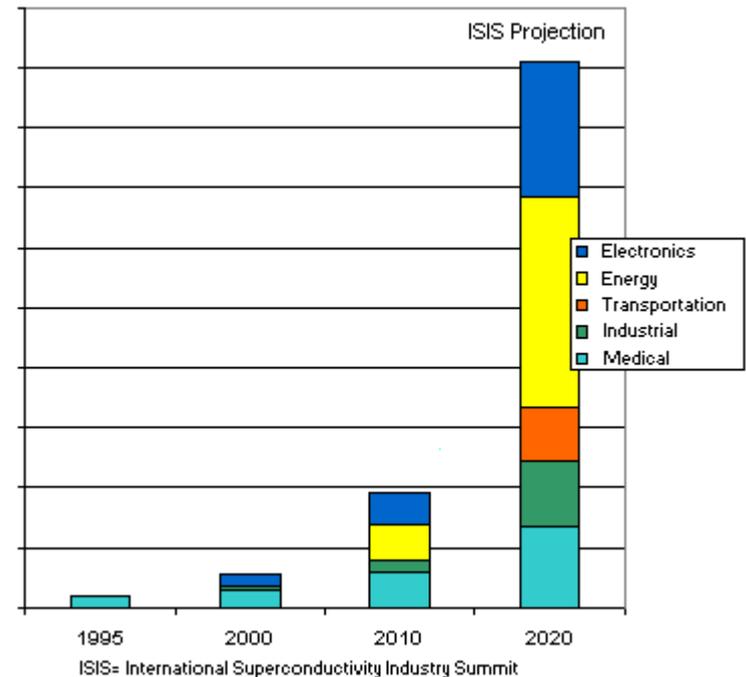


MRI scan of a brain

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The future of Superconductors

- * Estimated market worth of US \$38 billion by 2020
- * Graph shows a rough breakdown of market areas
- * The discovery of practical High Temperature superconductors could change the market overnight!



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Experimental Weapons

Modern Topics: Experimental Weapons

Sonic weapons

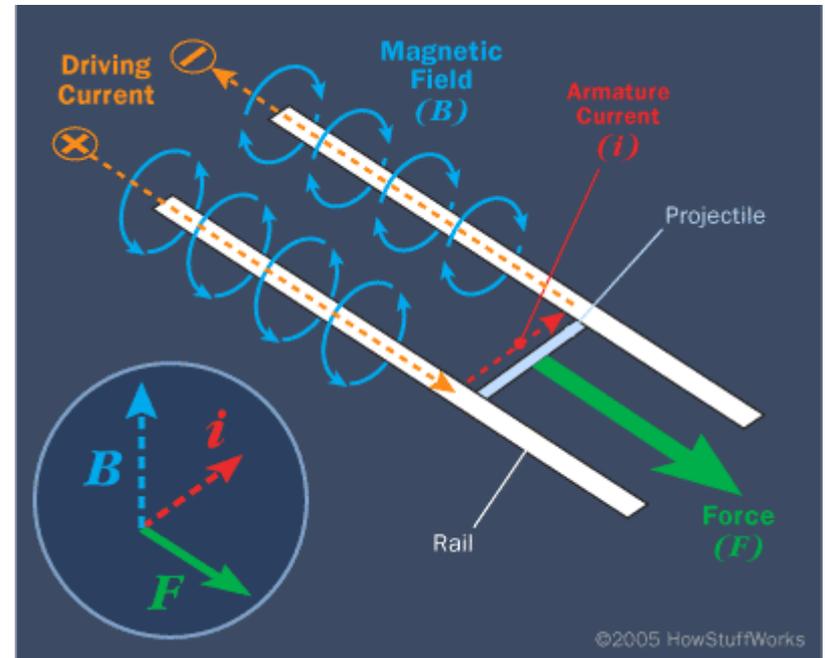
- * Utilise sound of various frequencies to cause discomfort, nausea and pain.
- * Can affect targets wearing body armour or hiding behind cover.
- * Anti-Teenager devices
- * Crowd dispersal / Riot control

Modern Topics: Experimental Weapons

Railguns

$$F = iL \times B$$

- * Use the Lorentz effect to accelerate a projectile.
- * Velocities in excess of 3500 m/s.
- * Best measure of effectiveness is energy transferred.
- * 9MJ device =>> 2kg at 3000m/s
- * Record held by British Aerospace, with a 33MJ laboratory weapon.



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Railguns compared with conventional weapons

Advantages:

- * Lighter and smaller ammo.
- * Greater range
- * Greater accuracy
- * Ability to target aircraft
- * Greater destructive potential

Disadvantages:

- * Requires bursts of very high electrical current
- * Limited by resistance of rail material
- * Possible EMP effect due to current

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Laser weapons

Targeting systems

Directed Energy Weapons

- * “Echo” location, target designation.
- * “ZEUS” – safe detonation of mines.
- * Laser weapon / Death ray

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Lasers compared with conventional weapons

Advantages:

- * Limitless Ammunition
- * No recoil
- * Greater accuracy
- * Ability to target aircraft
- * Ability to target missiles

Disadvantages:

- * Blooming – Dust and Smoke
- * Direct fire only