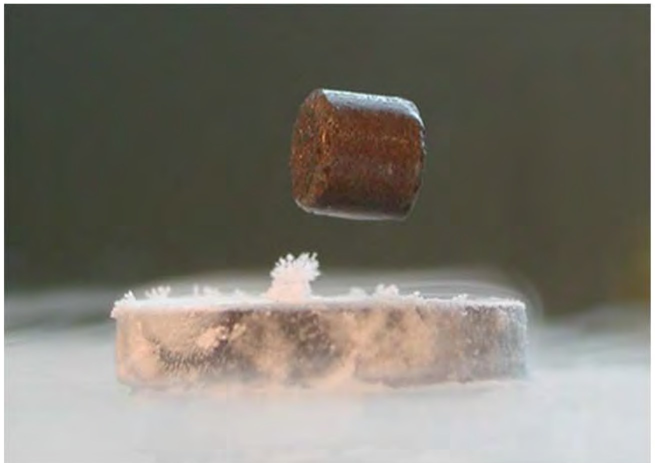
Supraconductivité: La magie du monde quantique devant vos yeux.

André-Marie Tremblay



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VERITATEM IN CHARITATE

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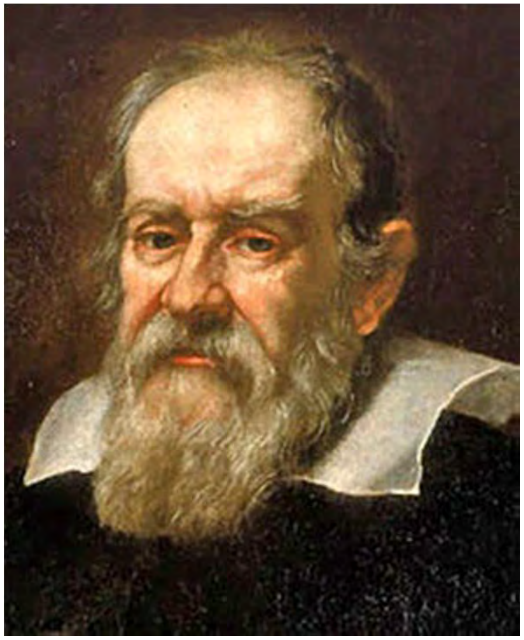
Galileo Galilei



1564-1642

Richard Feynman

1918-1988

Quelle serait la phrase qui contiendrait le plus d’information dans le moins de mots?

Atomes - température

La course vers la température zéro

Un pas important vers *T = 0*

- Heike Kamerlingh Onnes
  (Leiden) (1853/1926)

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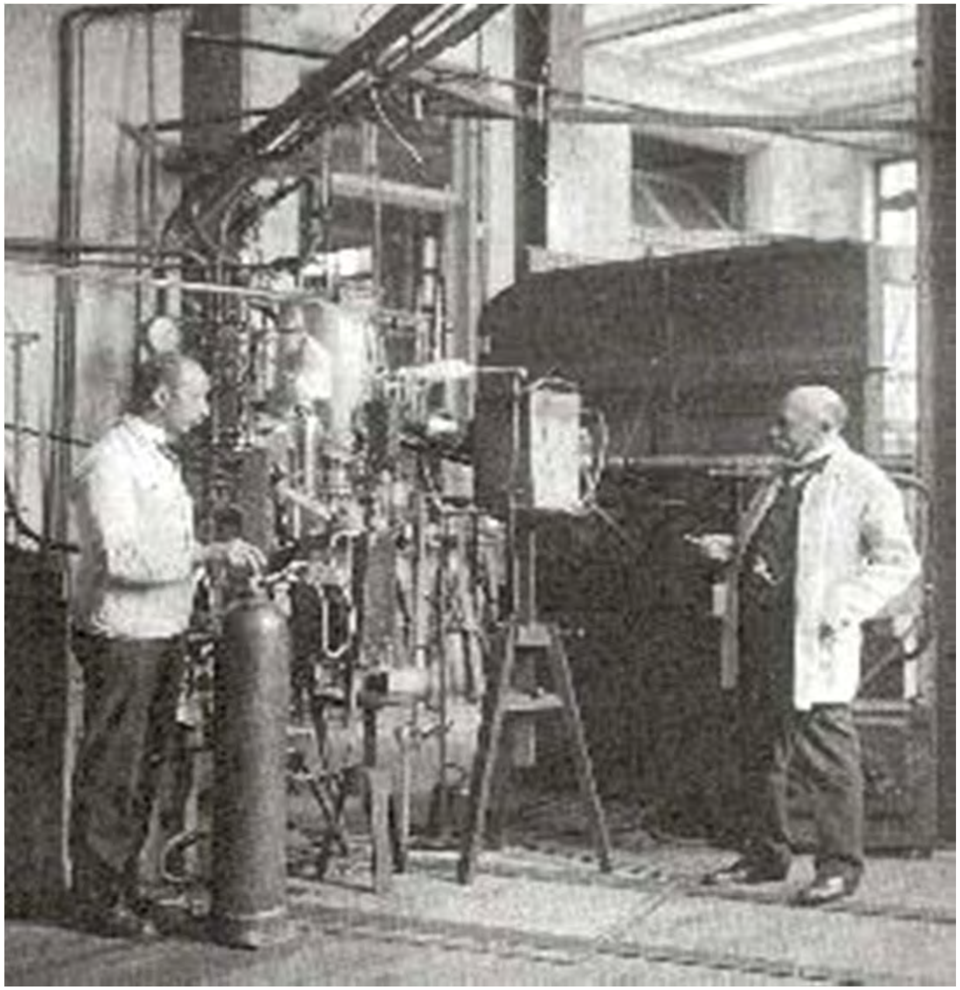
Les débuts du travail d'équipe en recherche

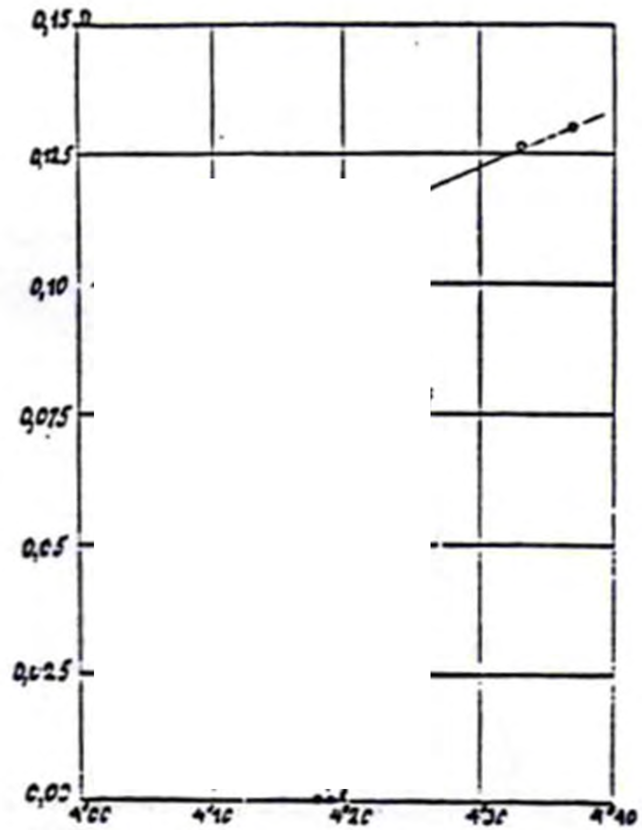
J.G.. Flim, cryogénie
G. Dorsma: thermométrie
G. Holst: électronique
Souffleur de verre



Et alors?

- Qu'arrive-t-il à la résistance électrique?

8 avril 1911



Congrès Solvay, 1911

Et le gagnant est…

- Heike Kamerlingh Onnes (Leiden) (1853/1926)

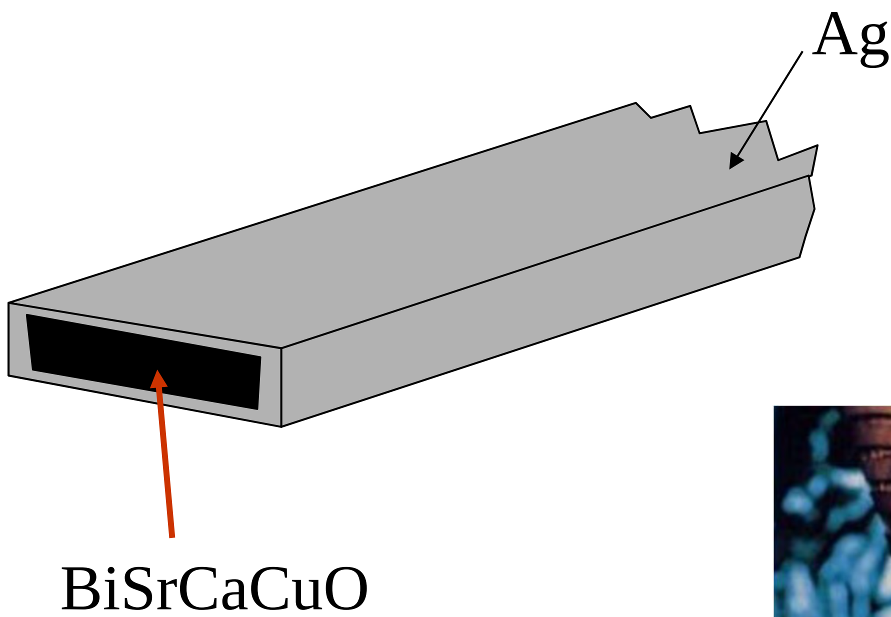
http://www.nobel.se

1913: Prix Nobel de physique

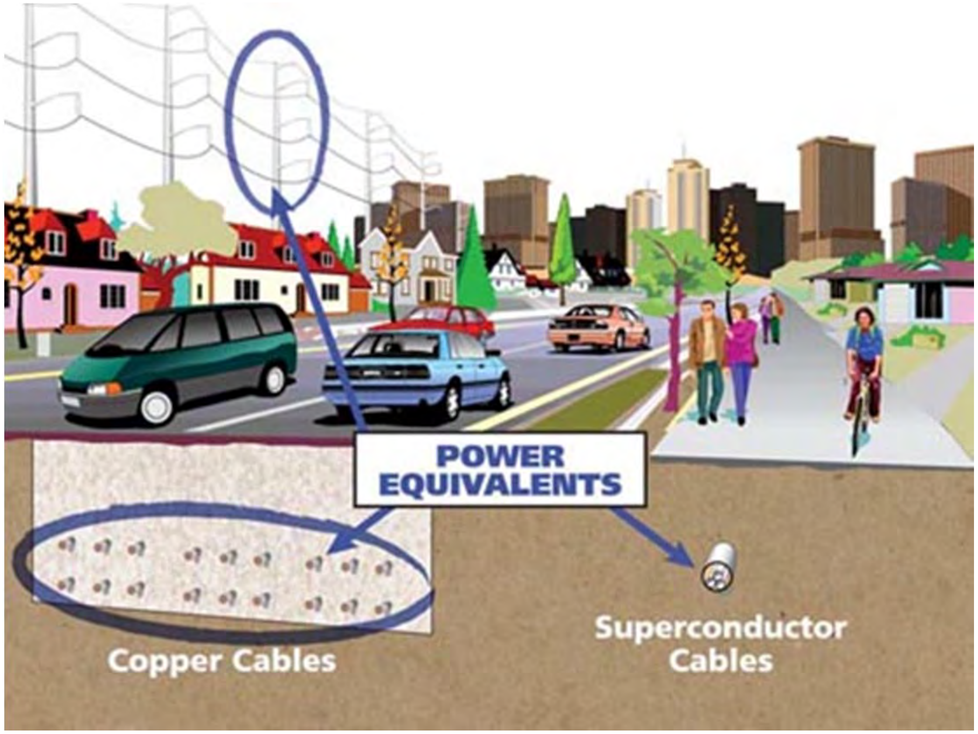
Au Professeur H. Kamerlingh Onnes de Leiden, pour ses expériences sur les propriétés de la matière à basse température qui ont conduit, concomitamment à la production de l'hélium liquide.

Transmission de l’électricité

Câbles



7 octobre 2010, American Superconductors



3,000 km de câbles pour la Corée du sud

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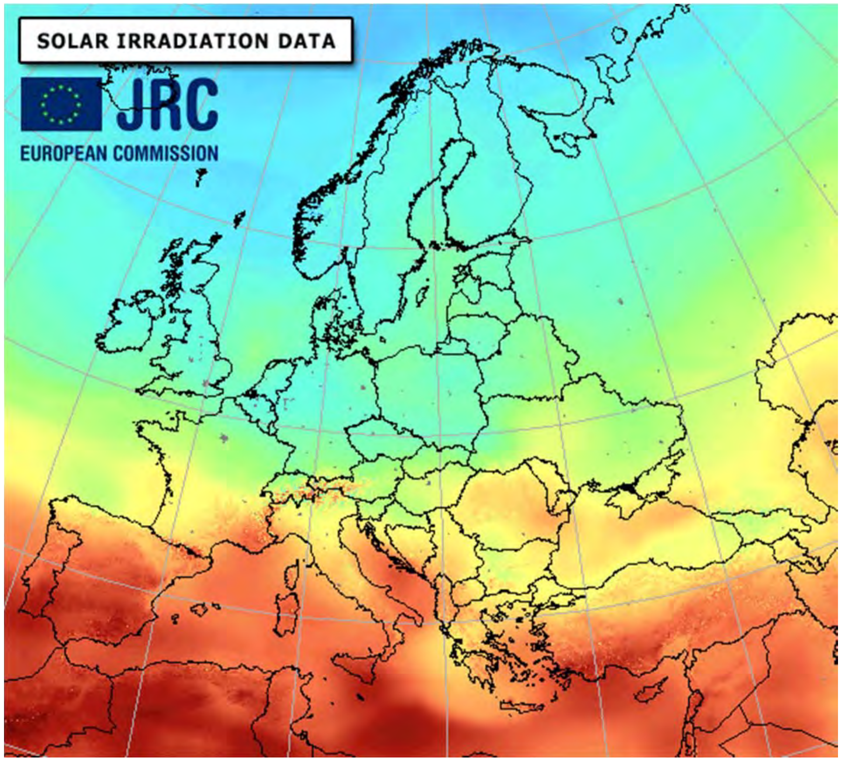
Production et besoin



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Tourner en rond tout en faisant quelque chose d'utile

André-Marie Ampère

1775 - 1836

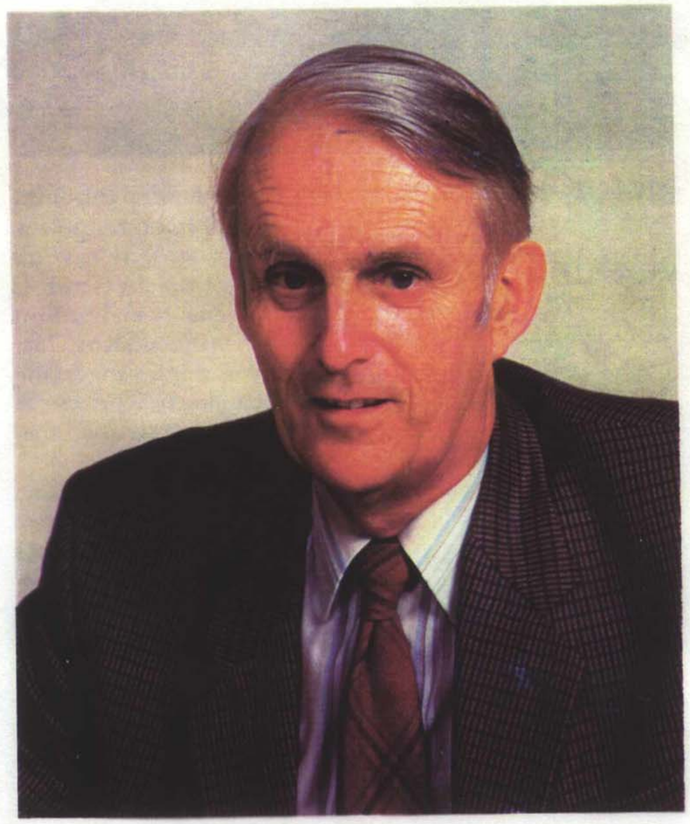
Le premier aimant supraconducteur

Martin

Wood, 1962

Supercurrents

The Superconductivity Magazine



Sir Martin Wood
Founder, Oxford Instruments

Transport des personnes

Maglev, aéroport de Shangai

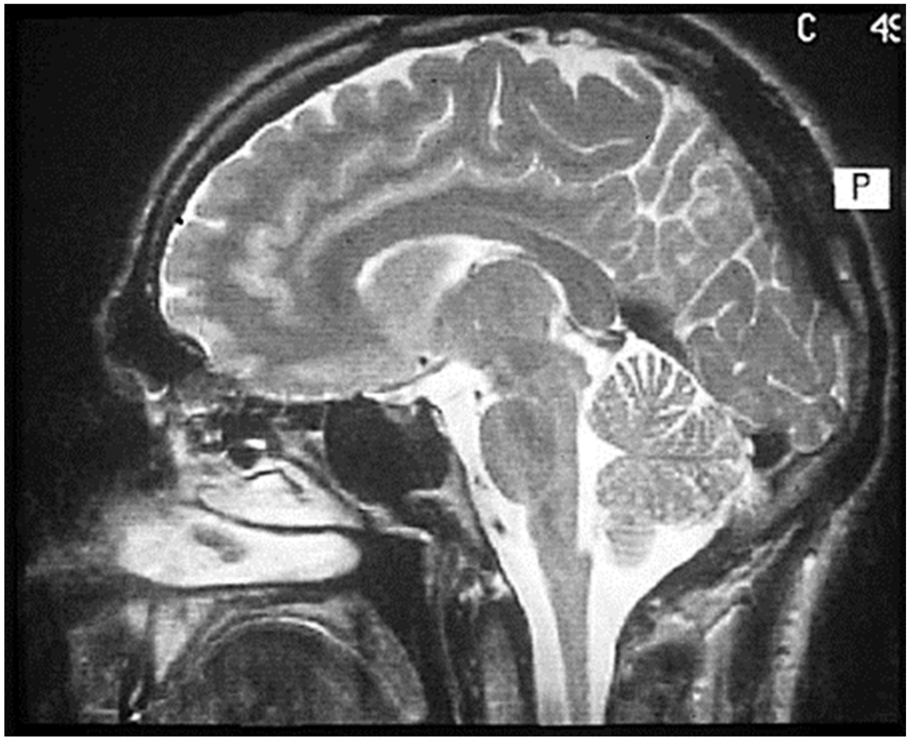
350 km/h (220 mph) en 2 minutes,
Vitesse maximale 431 km/h (268 mph).
Record 12 novembre 2006, 501 km/h (311 mph).

Test, train à lévitation magnétique, Japan Rail

JR-MLX01 maglev train at Yamanashi test track

En médecine

Imagerie par résonnance magnétique



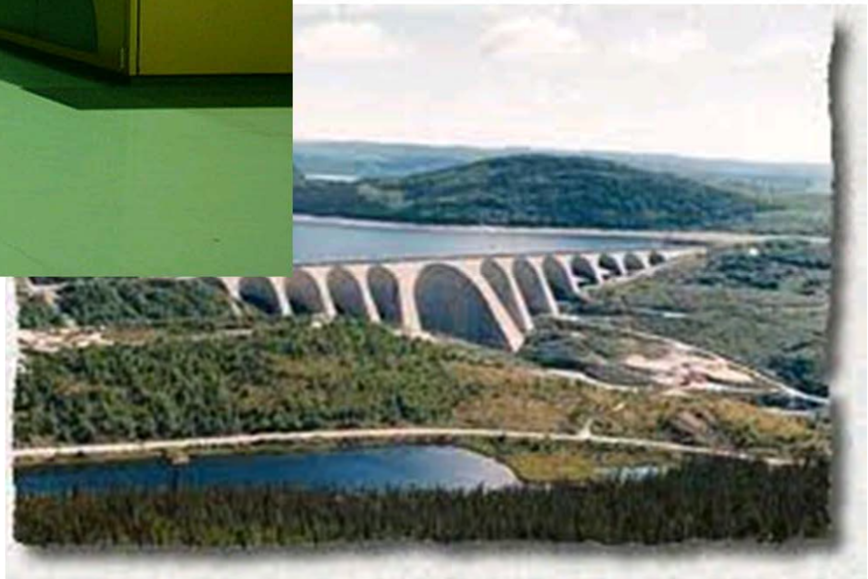
Et là où vous l’attendez le moins

De retour à la lévitation

Michael Faraday

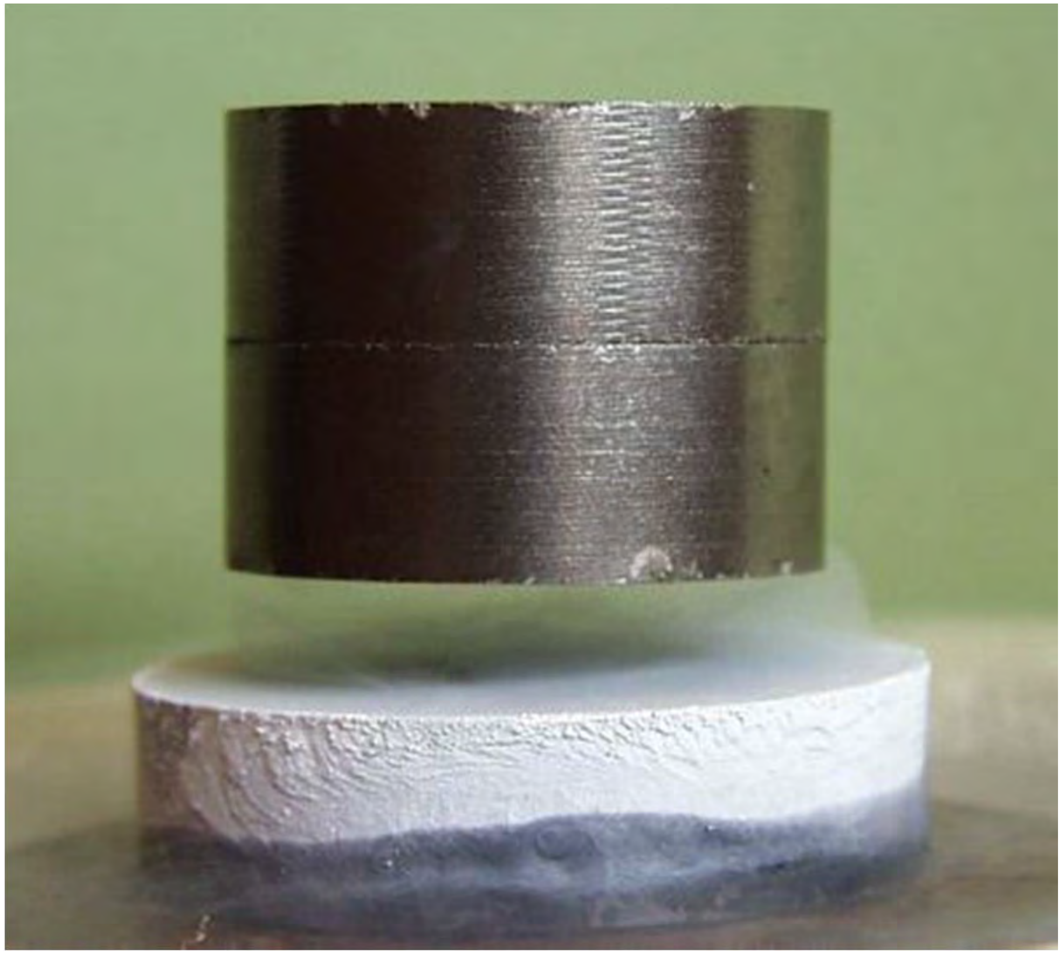
1791-1867

Induction



Walther Meissner
(1882-1974)

R. Ochsenfeld (1900-1992)

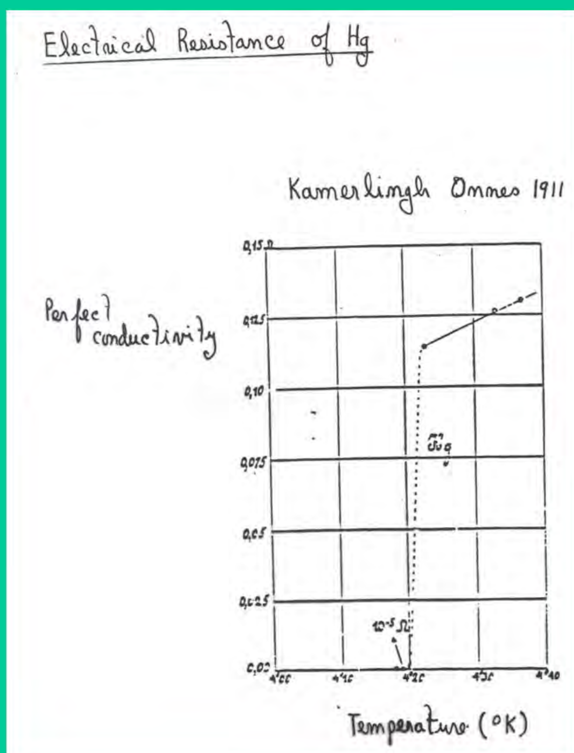


http://www.magnet.fsu.edu/education/tutorials/pioneers/meissner.html

http://kvphysics.blogspot.com/

Deux propriétés importantes

1. Zero resistance (if **B=0**)



2. Diamagnetism

OOKE

Comment explique-t-on la supraconductivité?

Théorème de Bloch, 1930

- On peut prouver que toutes les théories de la supraconductivité sont fausses.
- Feynman: personne n'est assez brillant pour trouver la solution.

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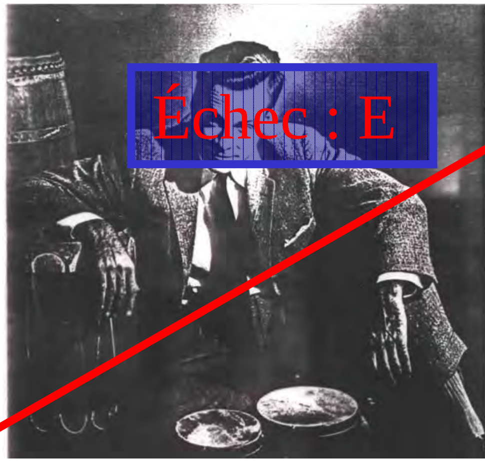
Quelques essais infructueux



Feynman

WERNER HEISENBERG (1901–) introduced matrix mechanics, which, like the Sch

Heisenberg

Bohr

NIELS BOHR (1885–1962) introduced the idea that the electron moved about the nucleus in well-defined orbits. This photograph was made in 1922, nine years after the publication of his paper

Einstein

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Une analogie

- Symétrie brisée
- Rigidité

BCS 1957

Comportement quantique à l'échelle macroscopique

Leon Cooper

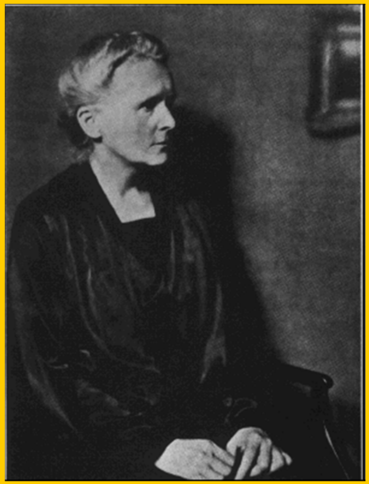
John Bardeen* Robert Schrieffer

Prix Nobel : 1972

- John Bardeen :
- Le seul à avoir obtenu deux prix Nobel en physique!!!

Invention : TRANSISTOR!

W. Shockley, J. Bardeen, W.H. Brattain



Marie Curie:

1903 Physique with H.A. Becquerel

1911 Chimie (seule)

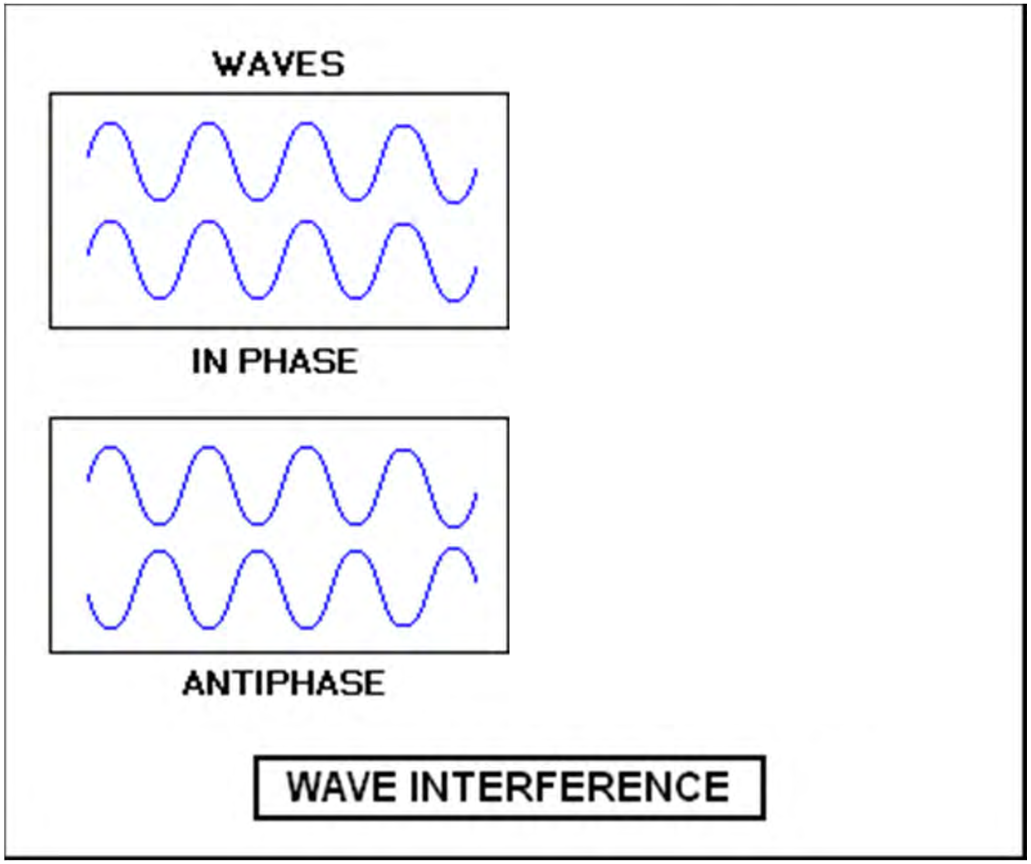
Ce qui était connu

- La résistance s'annulle
- L'effet Meissner
- Transparent aux microondes basse fréquence
- Effet isotopique

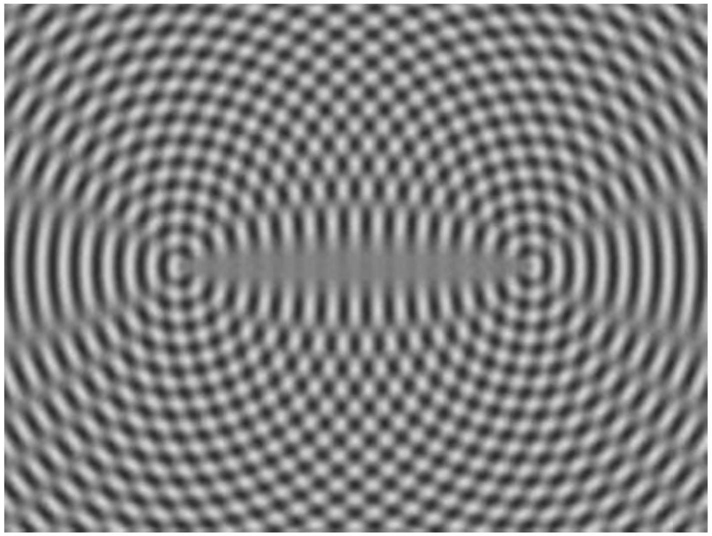
http://users-phys.au.dk/philip/pictures/physicsfigures/physicsfigures.html

Mécanisme d’attraction dans l’état métallique

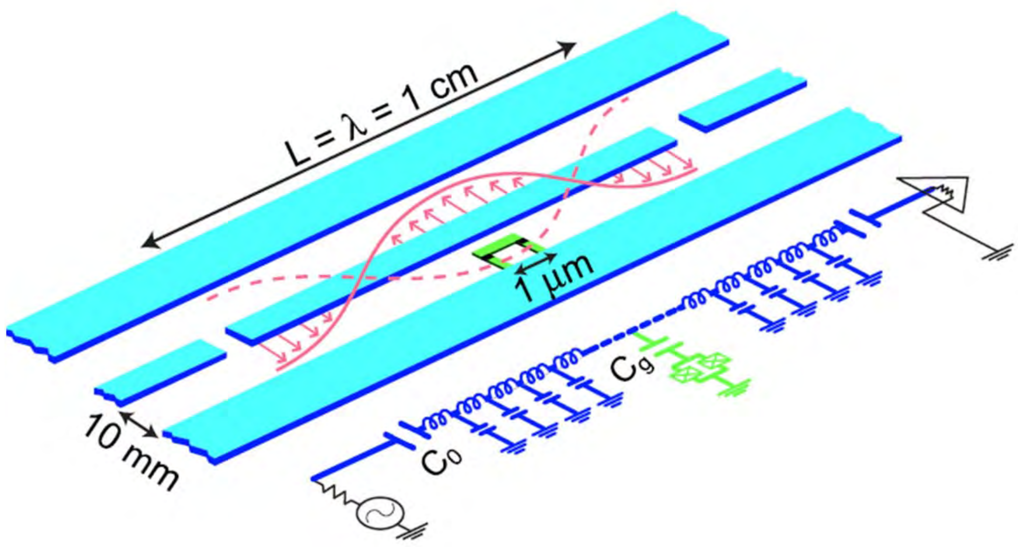
Ondes



Interférence



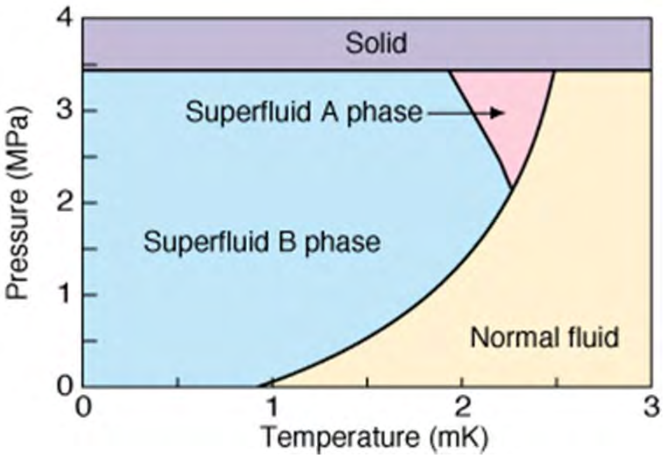
L’ordinateur quantique

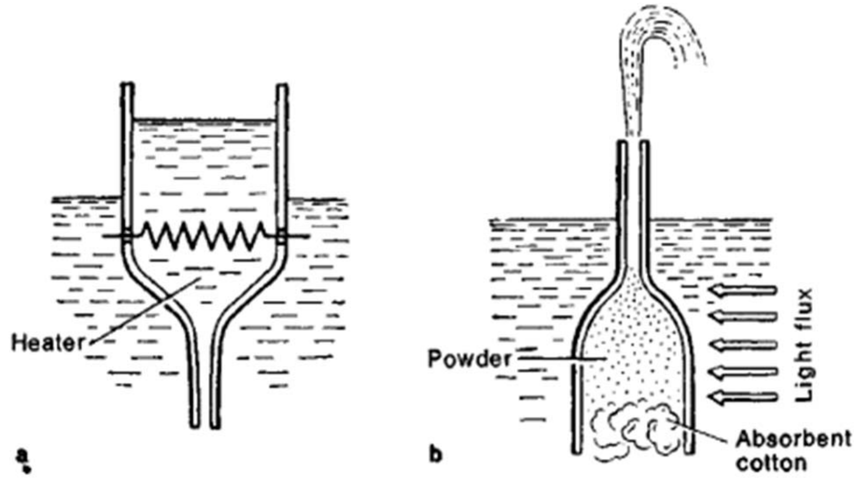


Alexandre Blais, et al. Phys. Rev. A **69**, 062320 (2004)

La supraconductivité partout

^{3}He superfluide





Le noyau des atomes (Rutherford 1911)

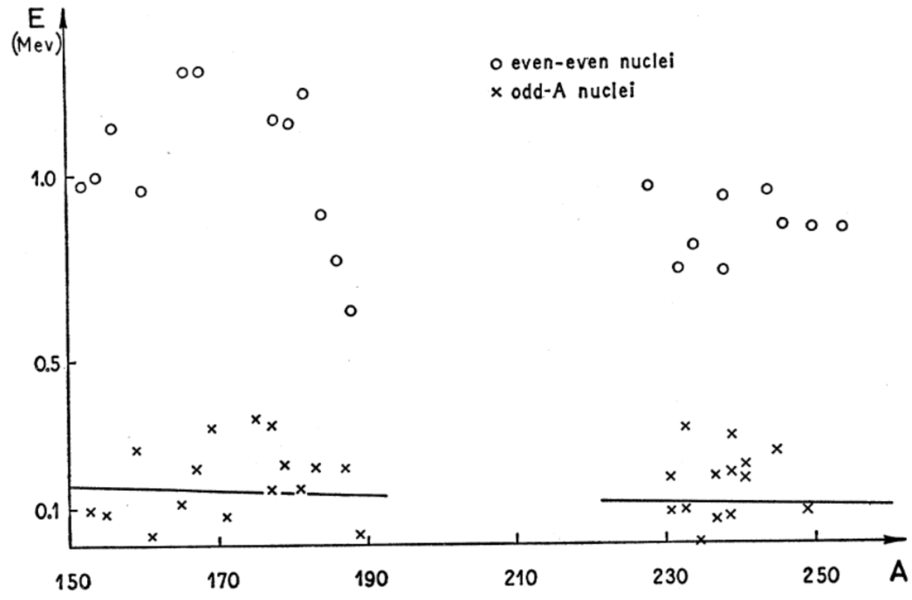
PHYSICAL REVIEW VOLUME 110, NUMBER 4 MAY 15, 1958

Possible Analogy between the Excitation Spectra of Nuclei and Those of the Superconducting Metallic State

A. Bohr, B. R. Mottelson, and D. Pines*
Institute for Theoretical Physics, University of Copenhagen, Copenhagen, Denmark, and Nordisk Institut for Teoretisk Atomfysik, Copenhagen, Denmark

(Received January 7, 1958)

The evidence for an energy gap in the intrinsic excitation spectrum of nuclei is reviewed. A possible analogy between this effect and the energy gap observed in the electronic excitation of a superconducting metal is suggested.



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Les étoiles à neutron

La nébuleuse du crabe (4 juillet 1054) en bleu et blanc
Credit & Copyright: Jay Gallagher (U. Wisc.), WIYN, AURA, NOAO, NSF

Les atomes ultra-froids

Vol 443 | 26 October 2006 | **doi:10.1038/nature05224**

nature

LETTERS

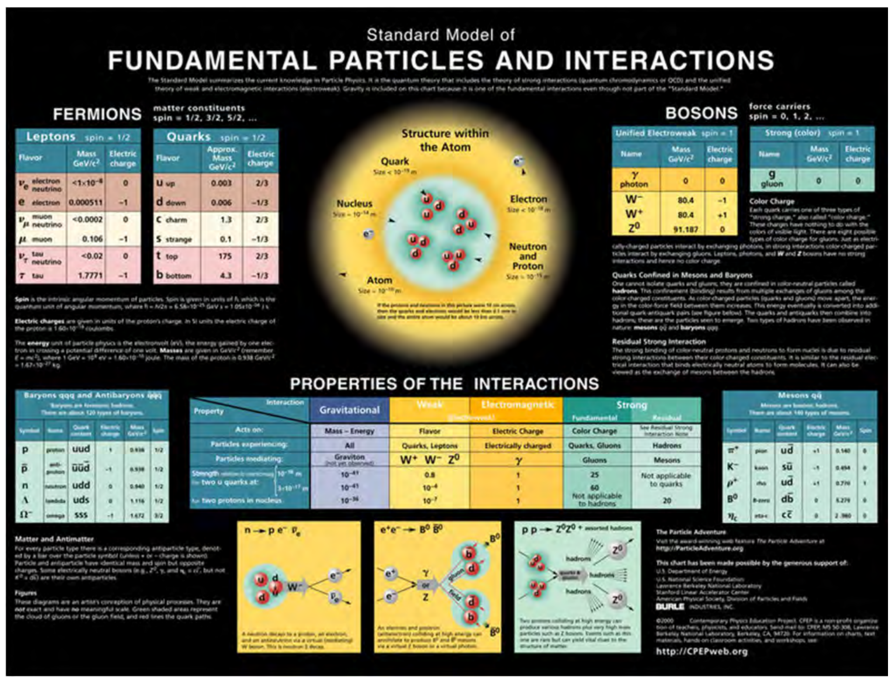
Evidence for superfluidity of ultracold fermions in an optical lattice

J. K. Chin[1], D. E. Miller[1], Y. Liu[1], C. Stan[1]†, W. Setiawan[1], C. Sanner[1], K. Xu[1] & W. Ketterle[1]

Le modèle standard des particules élémentaires (unification des interactions électro-faibles)

$$SU(2) \otimes U(1) \rightarrow U(1)$$

$$\begin{pmatrix} \phi_1 \\ \phi_2 \end{pmatrix} \rightarrow \begin{pmatrix} 0 \\ v \end{pmatrix}$$



Retour à l’histoire

Heureusement que tout n’était pas connu

- Résistance nulle (sauf s’il y a un aimant proche)
- L’effet Meissner (pas parfait)
- Parfois pas transparent aux micro-ondes
- Effet isotopique (parfois en direction opposée)

La théorie la mieux comprise

- En1969, R.D. Parks deux volumes « Superconductivity »

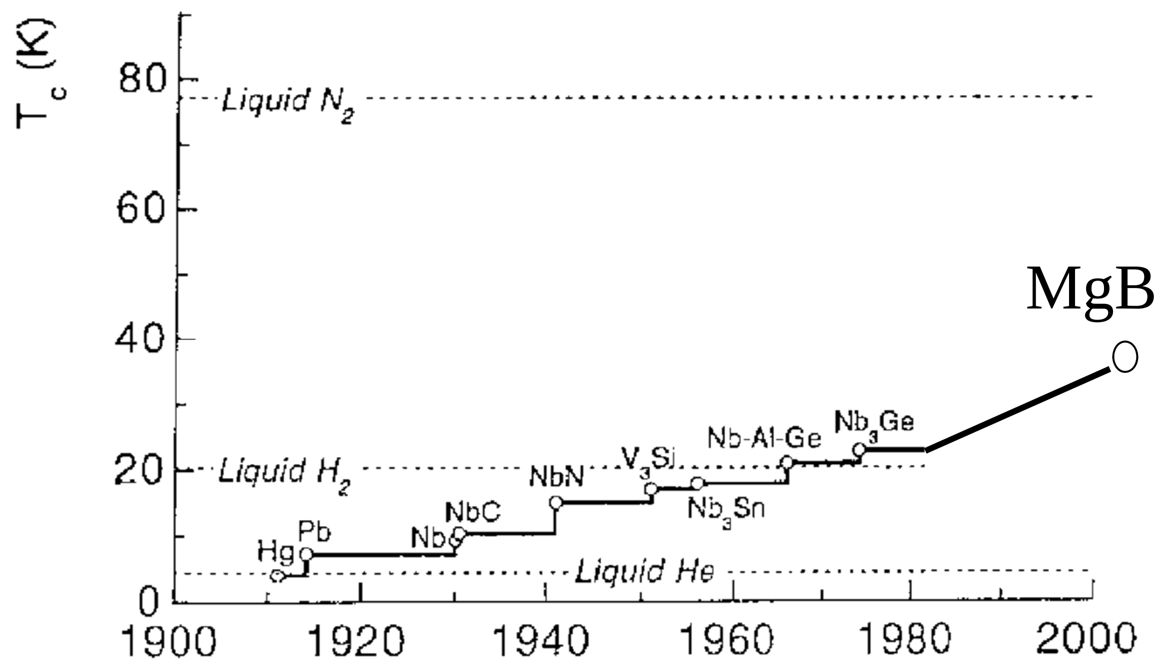
- D’un des auteurs: *« C’est le dernier clou dans le cercueil de la supraconductivité »*

La quête de nouveaux matériaux

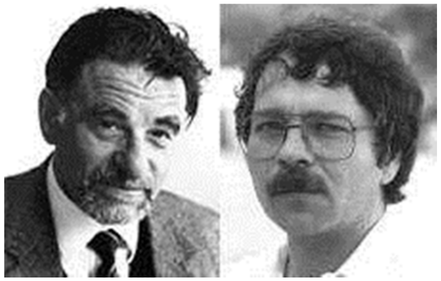
Le but: la température de l’azote liquide!

On croyait généralement que (1952)

- Métaux de transition (pas Cu,Au,Fe)
- Cubique
- Ne pas s'approcher de
  - O
  - Aimants
  - Isolants



Janvier1986



OSNI

1986 : Bednorz et Muëller, IBM Zurich

La-Ba-Cu-O $T_c \sim 30\text{-}40K$

Effet Meissner ?

Ça va vite…

- Boston, "Materials Research Society" Décembre 1986
  - –Koitchi Kitazawa et Shoji Tanaka Tokyo convainquent tout le monde.
- 16 février1987, Houston:
  - – Conférence de presse par Paul Chu pour annoncer la découverte de *Y-Ba-Cu-O*
  - – T_c = *93 K (vs 77 K)*

March meeting APS, 1987

- Titre du New York Times le lendemain:
"The Woodstock of Physics"

- 3000 personnes jusqu'à 3 heures du matin

"They began lining up outside the New York Hilton Sutton Ballroom at 5:30PM for an evening session that would last until 3:00 AM"

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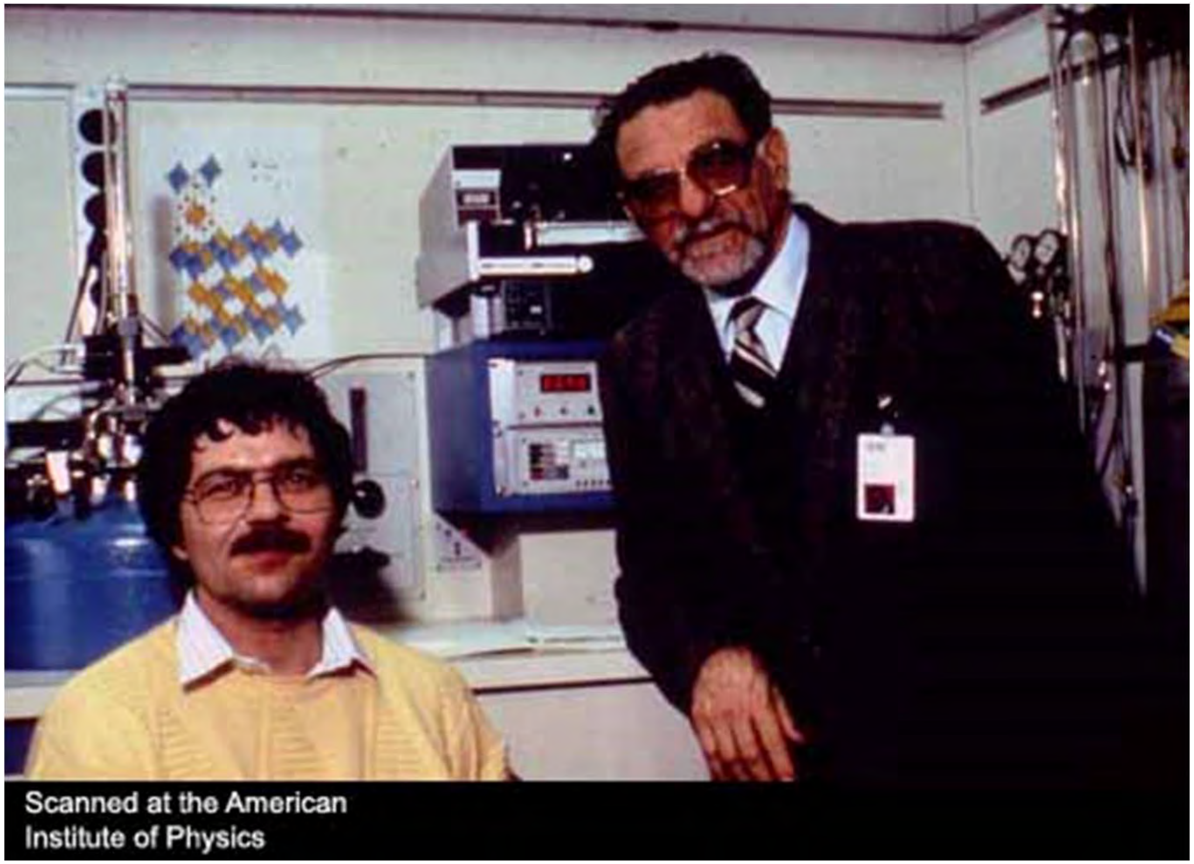
The "Woodstock of physics." On March 18, 1987, thousands of physicists crammed a ballroom at the New York Hilton to celebrate the coming of the age of superconductivity.

AMERICAN INSTITUTE OF PHYSICS

(right) Alex Müller, Paul Chu, and Shoji Tanaka, answering questions at the "Woodstock" meeting. Tanaka and Koichi Kitazawa were the first to confirm Bednorz and Müller's discovery, launching a worldwide race to find still better superconductors.

AMERICAN INSTITUTE OF PHYSICS



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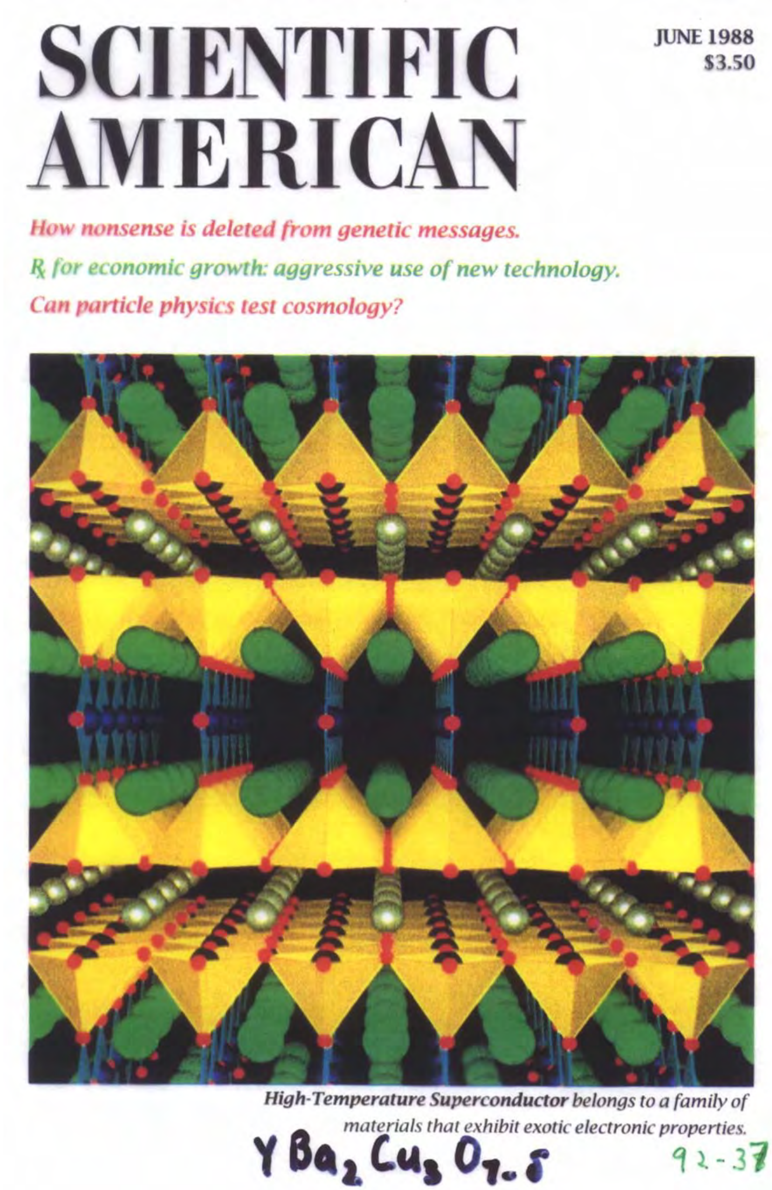
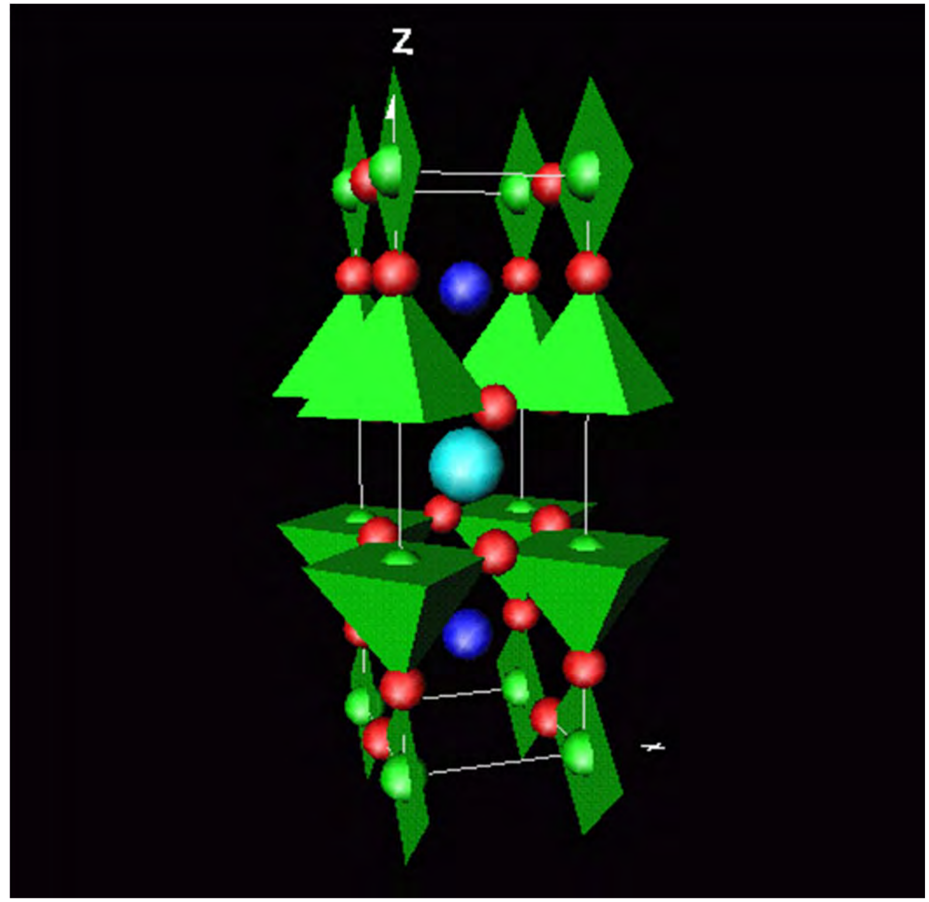
Ce qu'il y a de particulier avec ces supraconducteurs

Structure atomique





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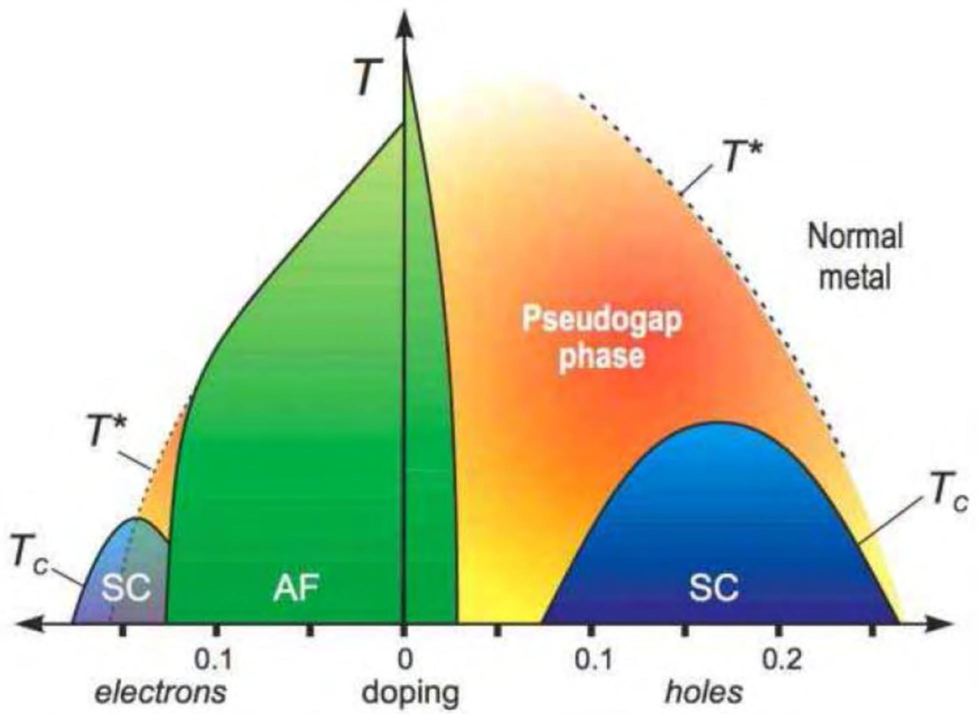
Ce qu'il y a de particulier

- Métaux de transition
- Cubique
- S'éloigner de
  - O
  - Aimants
  - Isolants

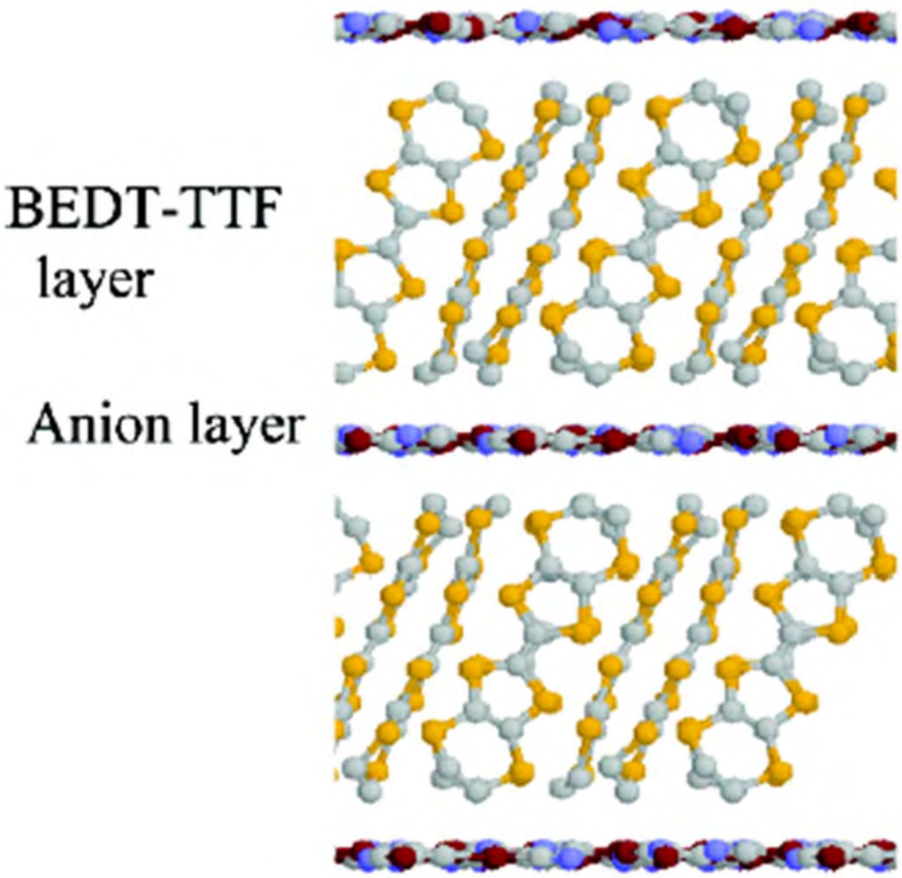
- Cu
- En couche
- Près de
  - O
  - Aimants
  - Isolants

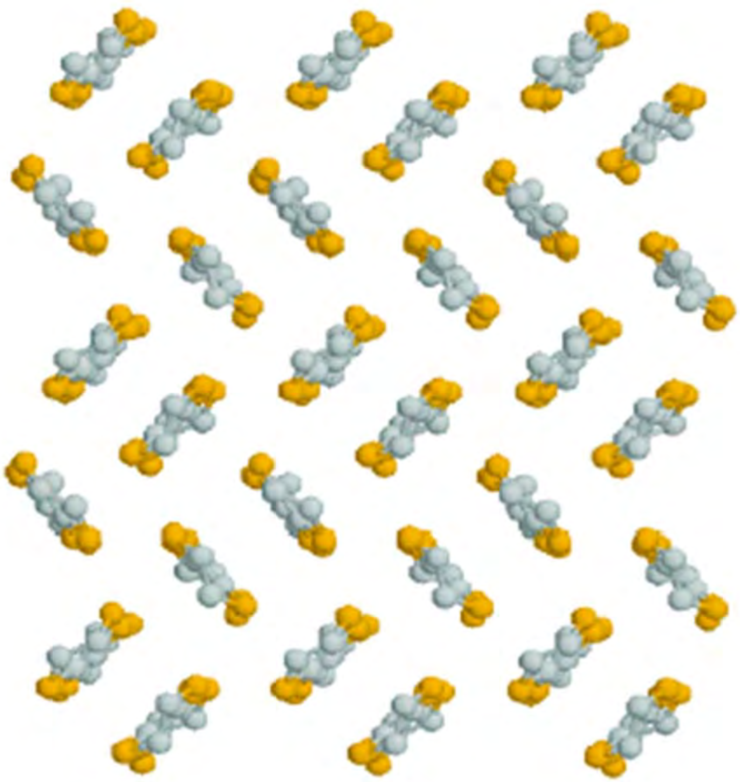
Diagramme de phase



Fischer et al. Rev. Mod. Phys. 79, 353 (2007)

Conducteurs organiques en couches (κ–BEDT-X)





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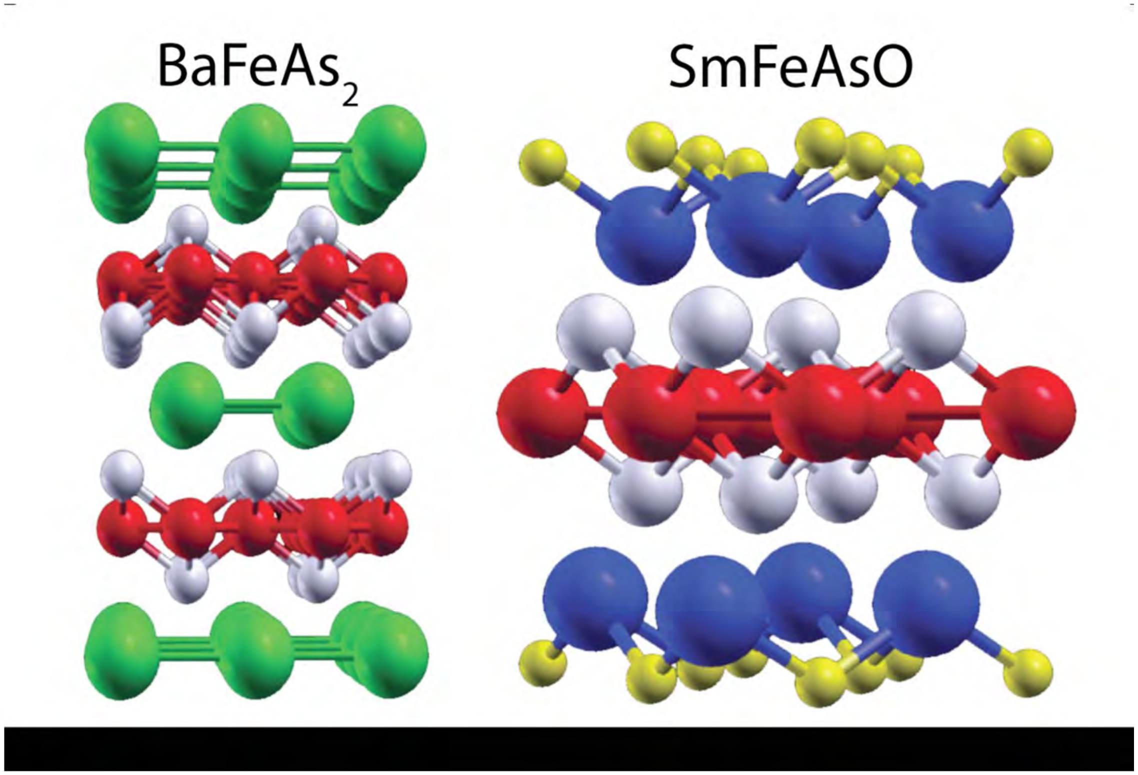
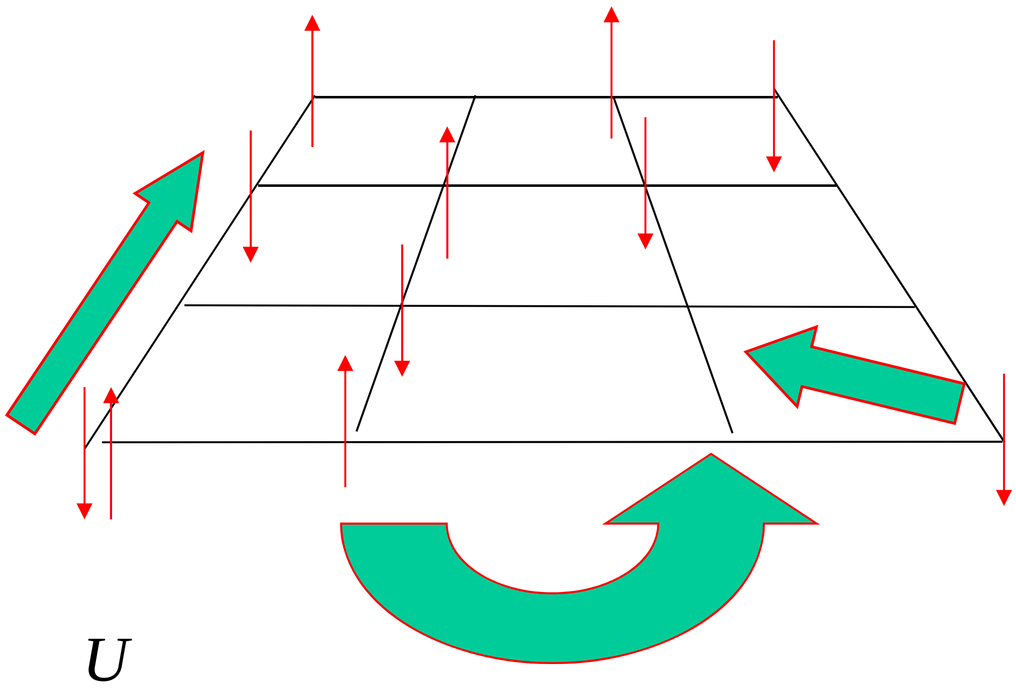
Pnictures (2008)

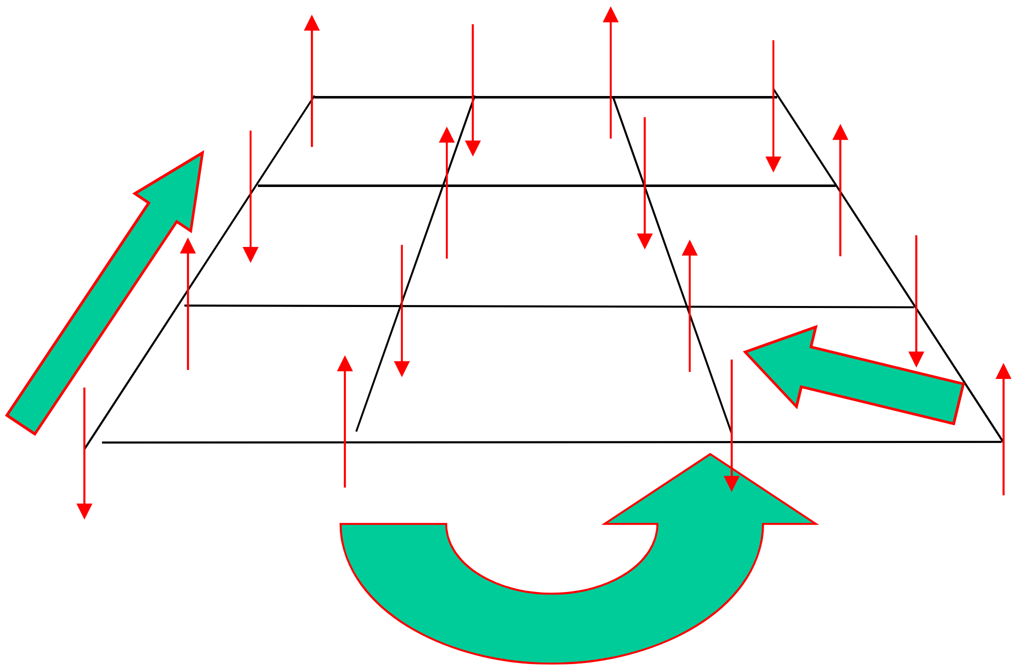


http://www.stanford.edu/~tpd/research_hightc.html

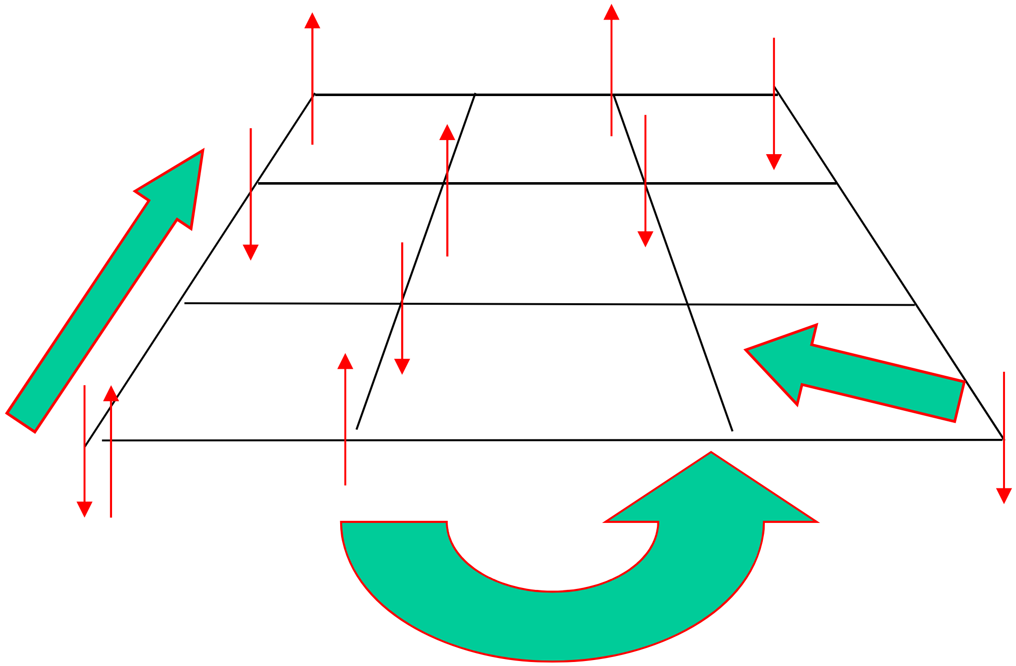
Pourquoi est-ce si difficile à comprendre?

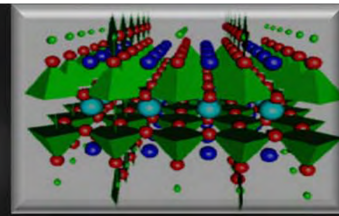


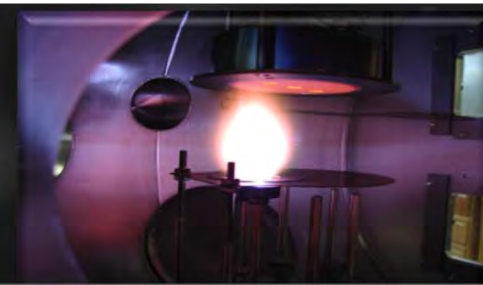
Isolant



Pourquoi est-ce si difficile à comprendre?

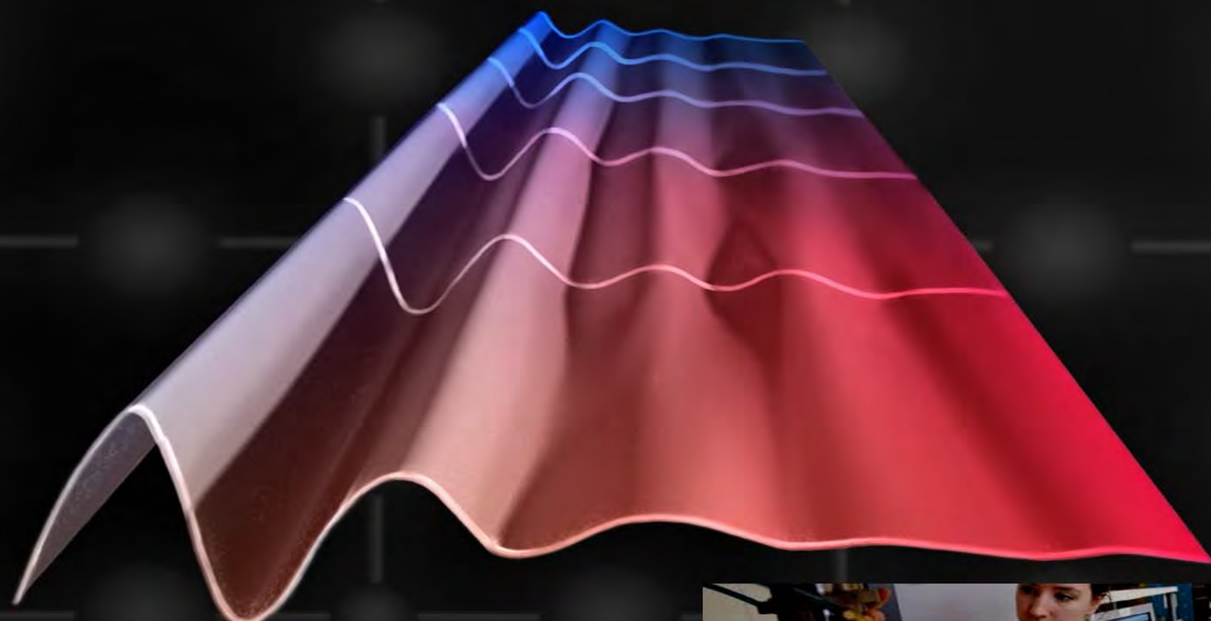




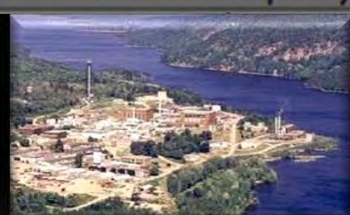


$$H(t) = -\sum_{ij\sigma} t_{ij} c^\dagger_{i\sigma} c_{j\sigma} e^{-i\int_i^j d\mathbf{r}_{ij}\cdot \mathbf{A}(\mathbf{r},t)} + U\sum_i n_{i\uparrow}n_{i\downarrow}$$

$$\Delta_{\mathbf{p}} = \frac{1}{V}\sum_{\mathbf{p}'} U\left(\mathbf{p}-\mathbf{p}'\right)\langle c_{-\mathbf{p}'\downarrow} c_{\mathbf{p}'\uparrow}\rangle$$



$$|BCS(\theta)\rangle = \cdots + \mathrm{e}^{iN\theta}|N\rangle + \mathrm{e}^{i(N+2)\theta}|N+2\rangle + \ldots$$



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Conclusion

Le rêve

room-temperature superconductors

50–50

They would transform the grid—if they can exist at all

By Michael Moyer

You can build a coal-fired power plant just about anywhere. Renewables, on the other hand, are finicky. The strongest winds blow across the high plains. The sun shines brightest on the desert. Transporting that energy into cities hundreds of kilometers away will be one of the great challenges of the switch to renewable energy.

The most advanced superconducting cable can move those megawatts thousands of kilometers with losses of only a few percent. Yet there is a catch: the cable must be kept in a bath of liquid nitrogen at 77 kelvins (or –196 degrees Celsius). This kind of deployment, in turn, requires pumps and refrigeration units every kilometer or so, greatly increasing the cost and complexity of superconducting cable projects.

Superconductors that work at ordinary temperatures and pressures would enable a truly global energy supply. The Saharan sun could power western Europe via superconducting cables strung across the floor of the Mediterranean Sea. Yet the trick to making a room-temperature superconductor is just as much of a mystery today as it was in 1986, when researchers constructed the first superconducting materials that worked at the relatively high temperatures of liquid nitrogen (previous substances needed to be chilled down to 23 kelvins or less).

Two years ago the discovery of an entirely new class of superconductor—one based on iron—raised hopes that theorists might be able to divine the mechanism at work in high-temperature superconductors [see "An Iron Key to High-Temperature Superconductivity?" by Graham P. Collins; Scientific American, August 2009]. With such insights in hand, perhaps a path toward room-temperature superconductors would come into view. But progress has remained slow. The winds of change don't always blow on cue.

www.ScientificAmerican.com

SCIENTIFIC AMERICAN 43

http://www.physique.usherbrooke.ca/taillefer/Vulgarisation.html

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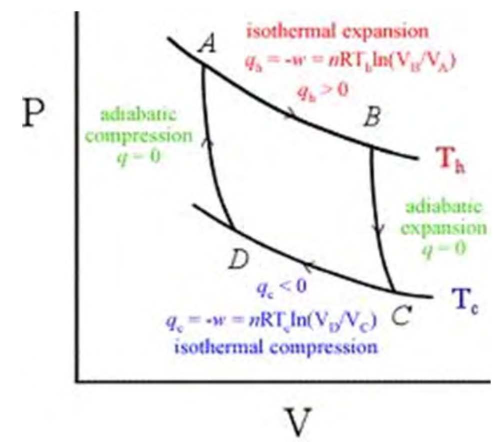
Science et technologie, main dans la main

Machine à vapeur et thermodynamique

Watts 1765



Carnot 1824

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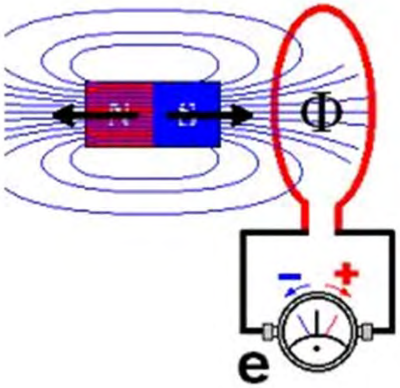
Induction et le moteur électrique

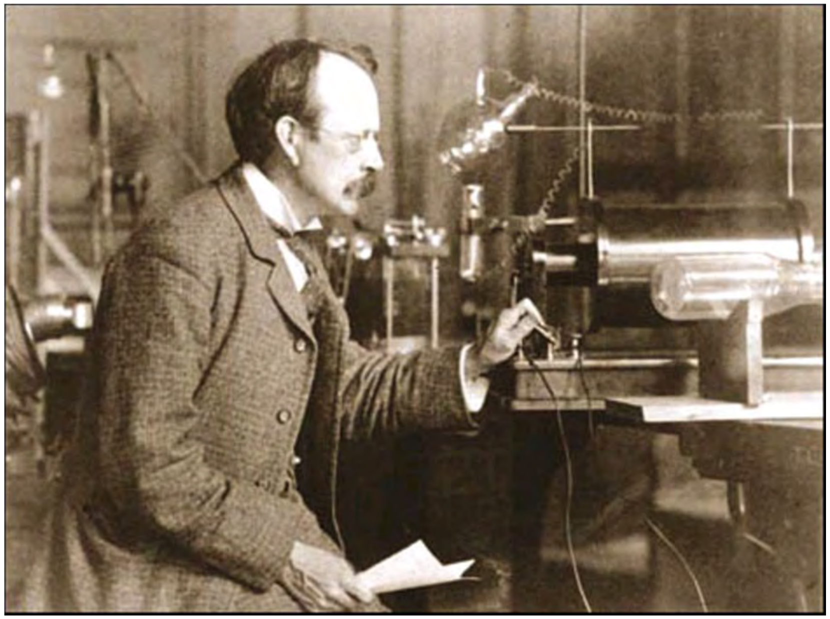
Moteur électrique, Tesla(1880)

Induction, Faraday (1831)



Induction

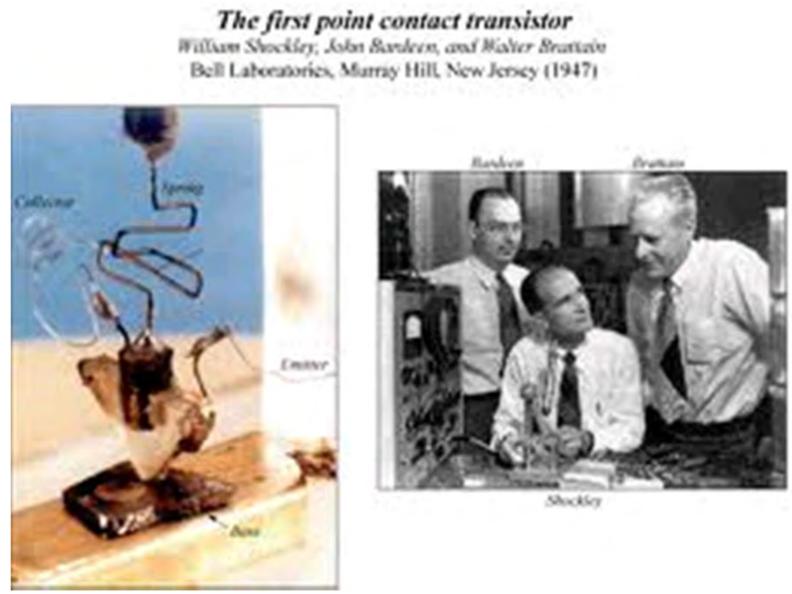
Électron and television



Thomson, 1897

Télévision, 1940

Mécanique quantique et le transistor



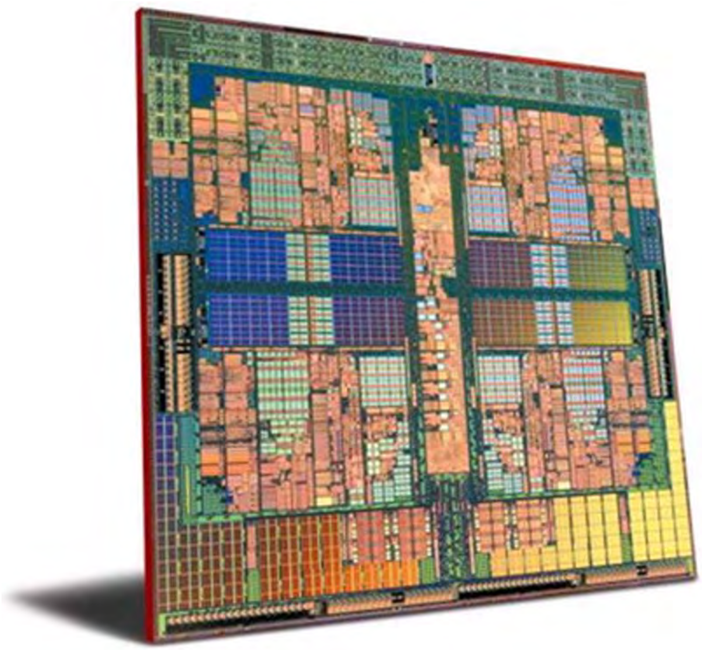
Schrödinger

Heisenberg

Transistor 1947

Mécanique quantique 1926

Mécanique quantique et le transistor



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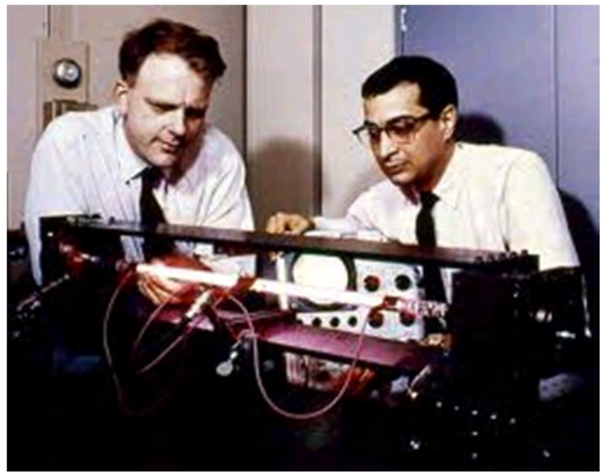
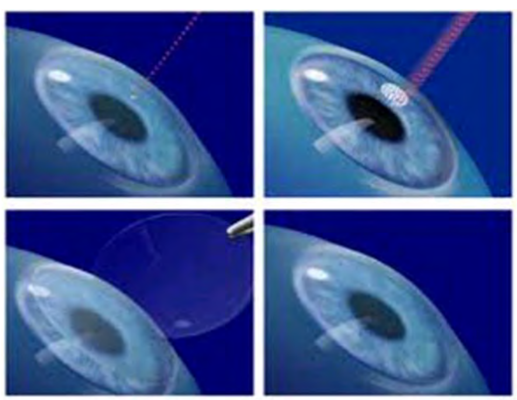
Laser et CD-ROM

Stimulated emission 1925



Laser 1960

CD-ROM (1980-90)



Chirurgie occulaire

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Edward Bellamy (USA) 1887

- Roman: « Looking backward » 2000-1887
- Si nous pouvions inventer un dispositif pour offrir à tous de la musique dans leur maison, qui serait de qualité parfaite, de quantité illimitée, pour toutes les humeurs et qui commencerait et s’arrêterait lorsqu’on voudrait, alors nous aurions atteint la limite du bonheur pour l’humanité et nous pourrions cesser de chercher des améliorations.

Merci

http://sweetladiesbakery.com/gallery/female-cakes/