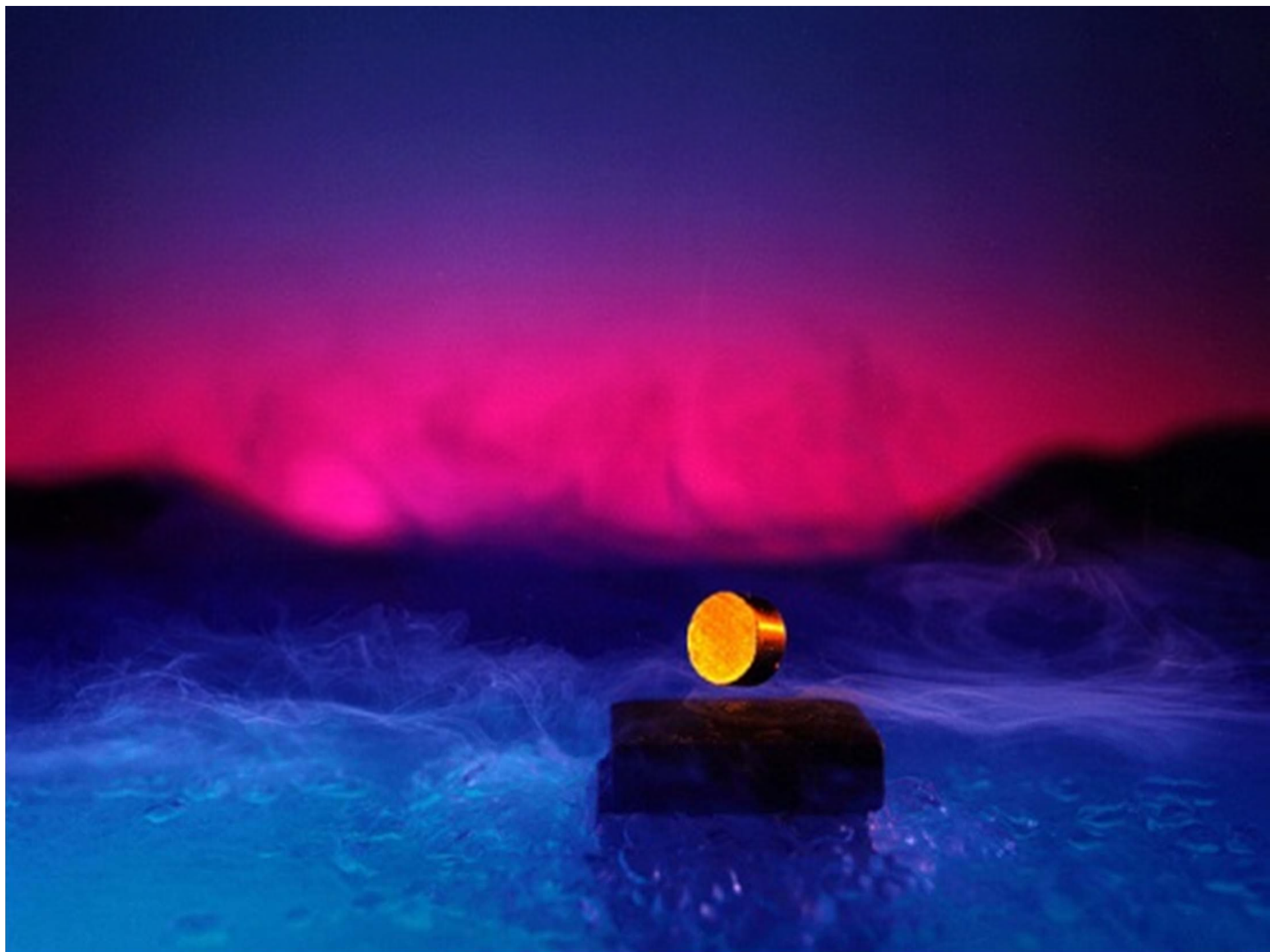




Richard Feynman



1918-1988



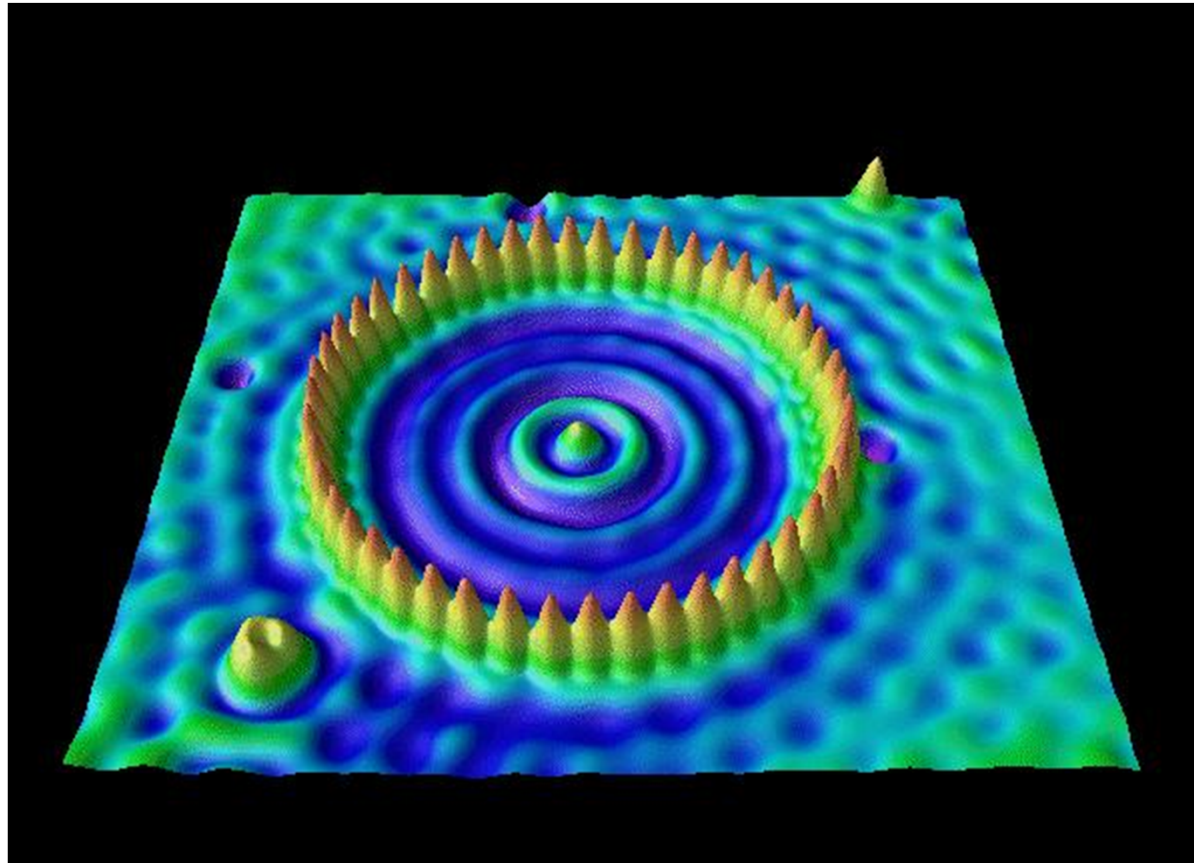
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Une idée utile



On peut « Voir » les atomes



Swiss Nanoscience Institute, Basel,
Switzerland

Fe sur Cu: 7 nm Eigler *et al.* 1993



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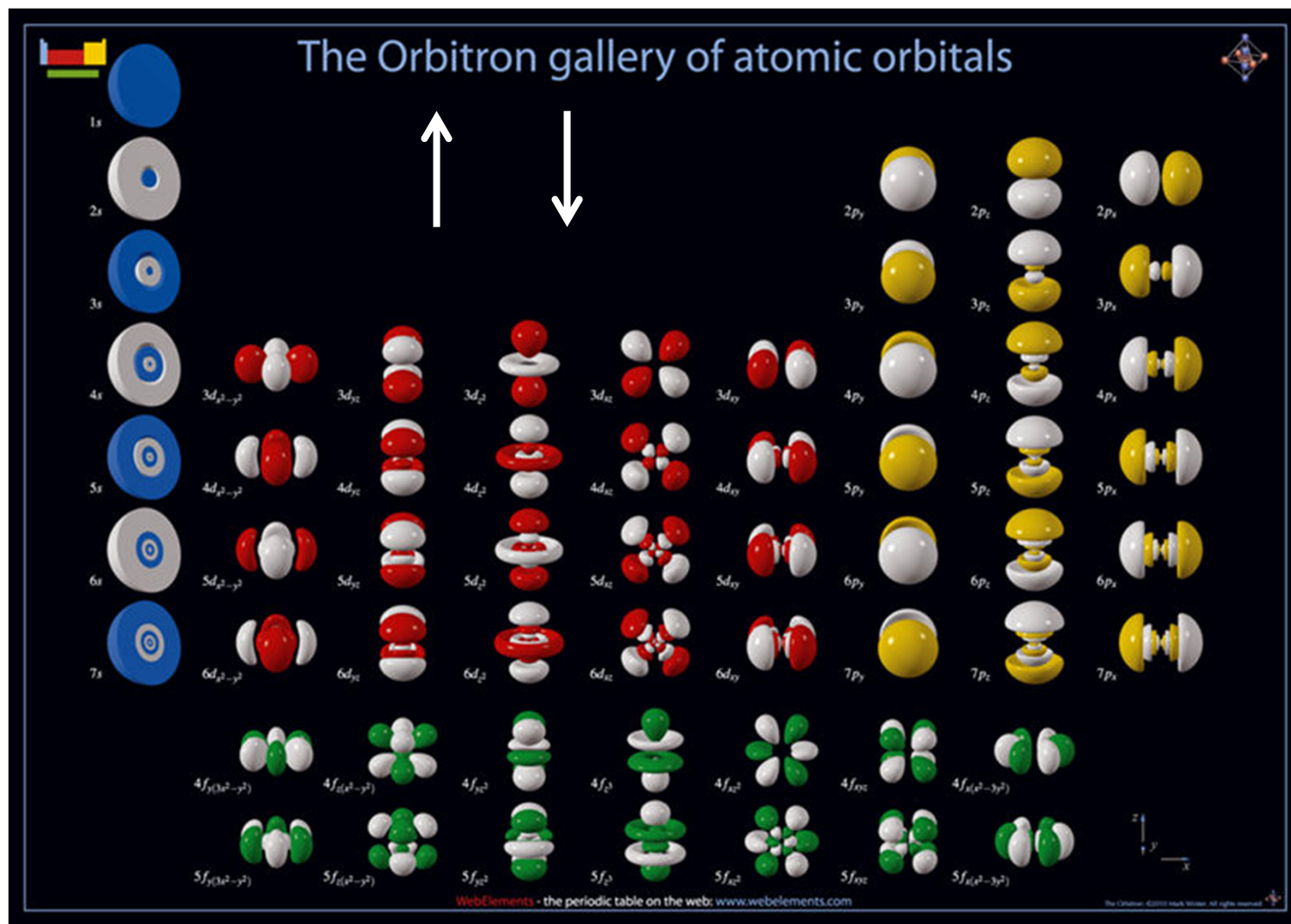
Théorie ondulatoire de la matière

$$\lambda = h/p$$

$$t_{osc} = h/E$$



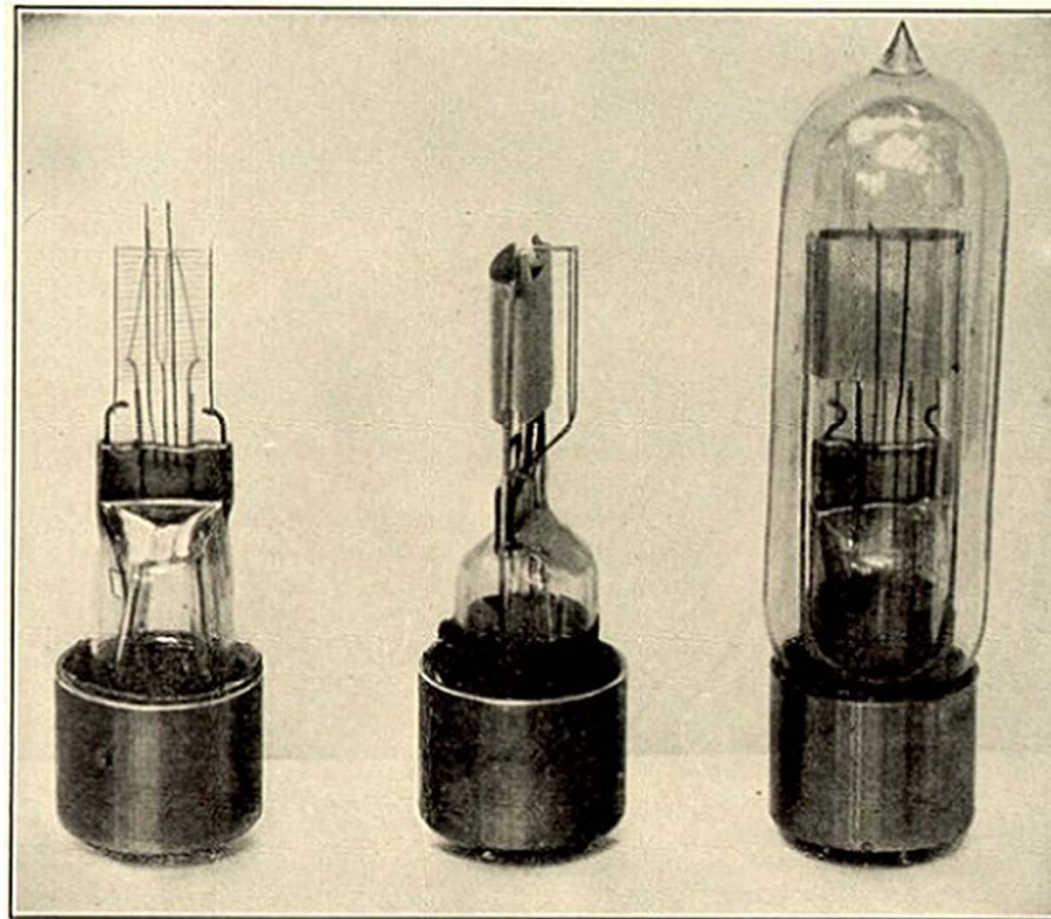
Orbitales atomiques et tableau périodique



Une première révolution technologique



Avant: les lampes à vide



Courtesy of the Radio Corporation of America.

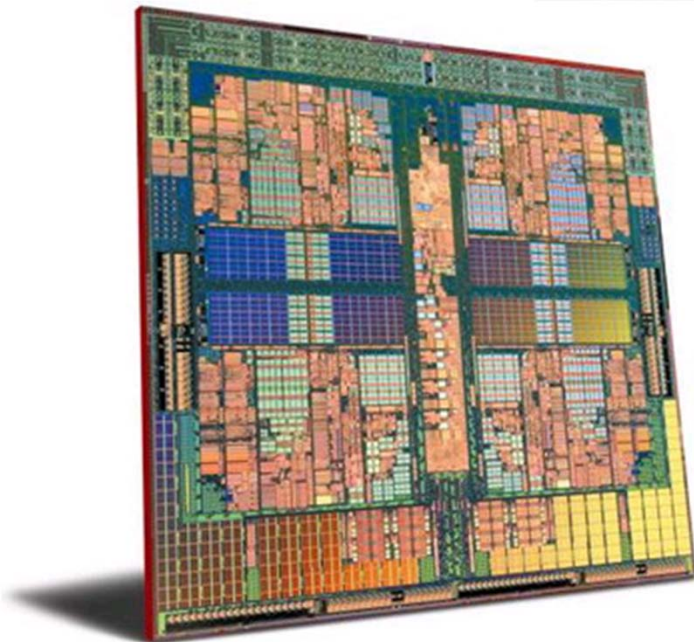
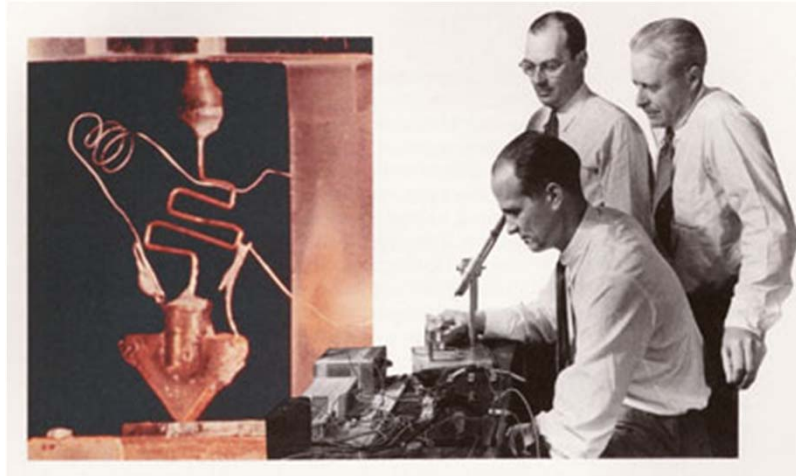
THE THREE ELEMENT VACUUM TUBE WHICH IS CHIEFLY RESPONSIBLE FOR THE RAPID DEVELOPMENT OF RADIO COMMUNICATION. THE FIRST VIEW ON THE LEFT SHOWS THE FILAMENT SURROUNDED BY THE GRID. IN THE CENTER VIEW THE PLATE HAS BEEN ADDED AND ON THE RIGHT IS THE COMPLETE TUBE.



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Le transistor

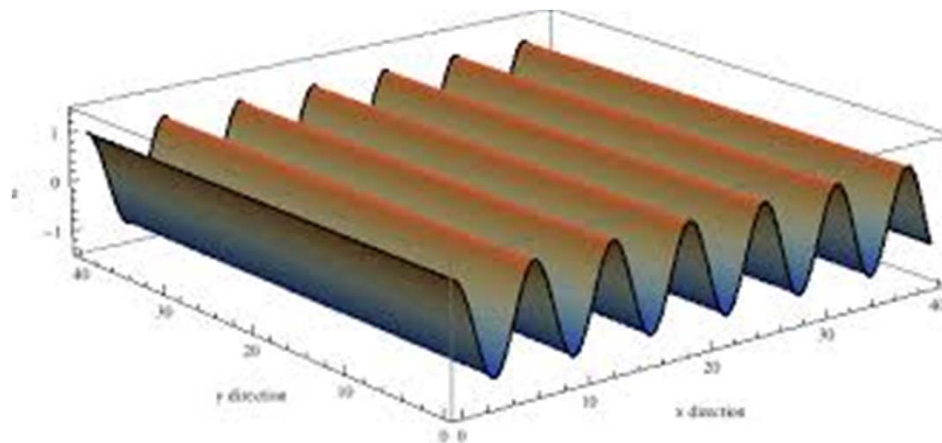
1947



Les retombées...



Électrons dans les solides



<http://phet.colorado.edu/fr/simulation/bound-states>



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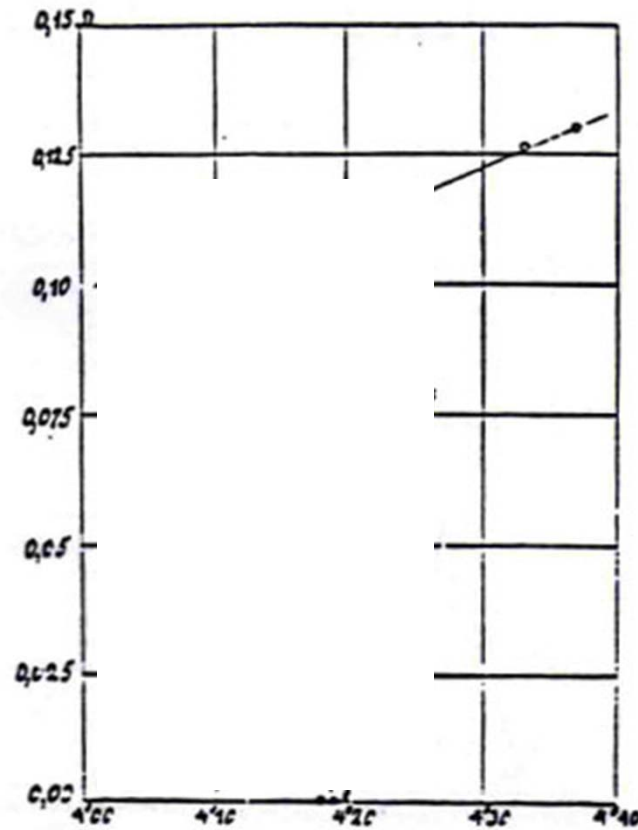
La supraconductivité: un phénomène quantique macroscopique



La découverte

- Qu'arrive-t-il à la résistance électrique à $T=0$?

8 avril 1911



Expulsion du champ magnétique

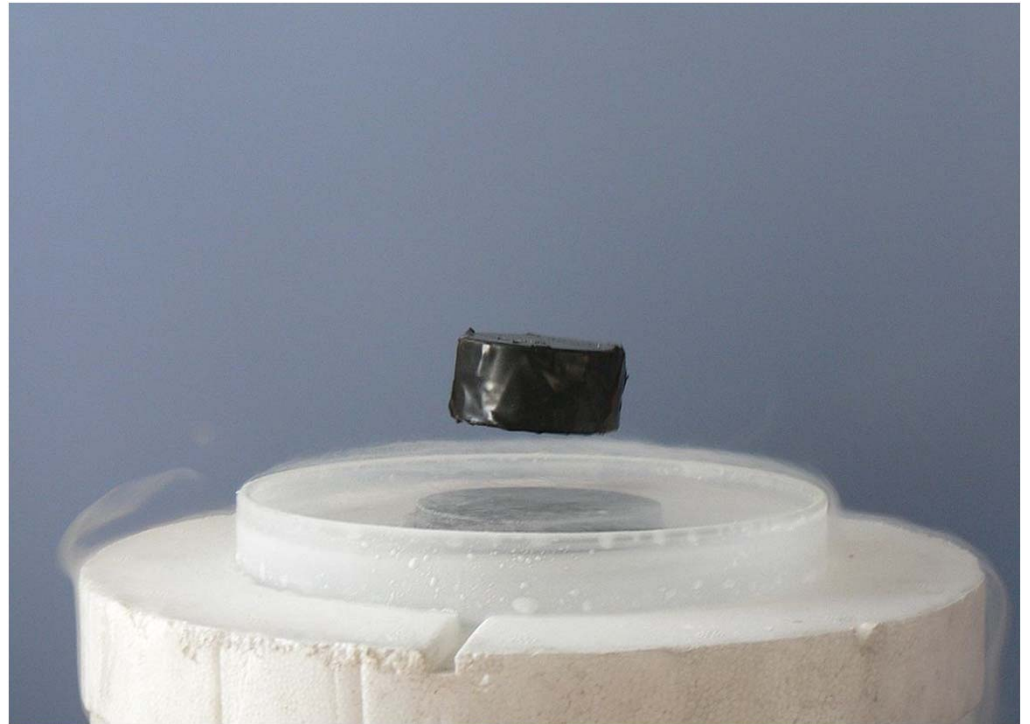


Walther Meissner
(1882-1974)



R. Ochsenfeld (1900-1992)

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



Un phénomène quantique macroscopique

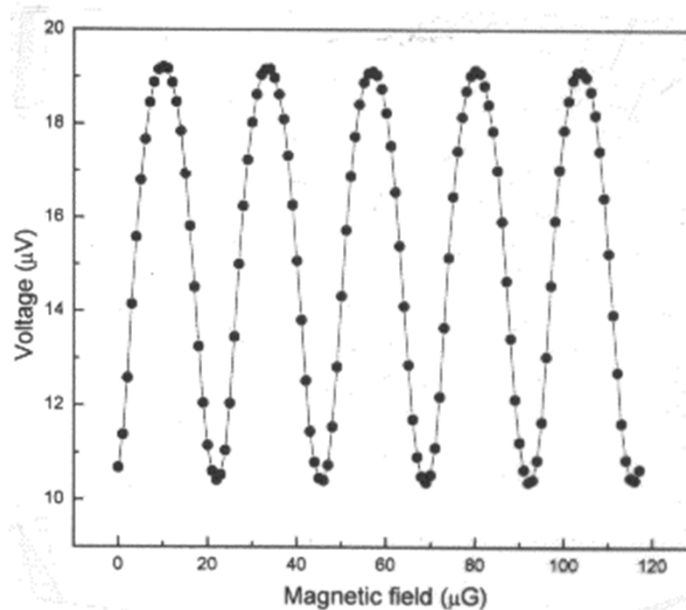
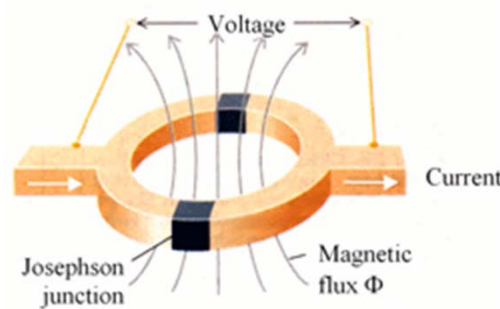


Figure 3. V - Φ characteristic of a typical DC SQUID. Output voltage is a periodic function of applied flux with the periodicity of a flux quantum Φ_0 .

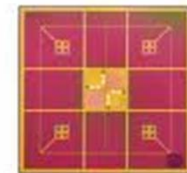
$$\Phi_0 = h/(2e)$$



SQUID Sensors



- 306 independent measurement channels.
- Organized in channel-triplets on 102 silicon chips:
 - Two planar gradiometers
 - One radial magnetometer



Retour à la mécanique quantique



La théorie la plus précise

- Expérience Phys. Rev. Lett. 97, 030801 (2006)

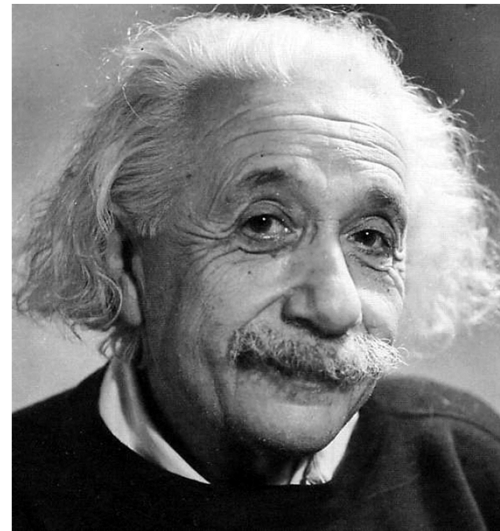
$$g/2 = \mathbf{1.001\ 159\ 652\ 188\ 4\ (4.3)}$$

- Calcul Phys. Rev. D 77, 053012 (2008)

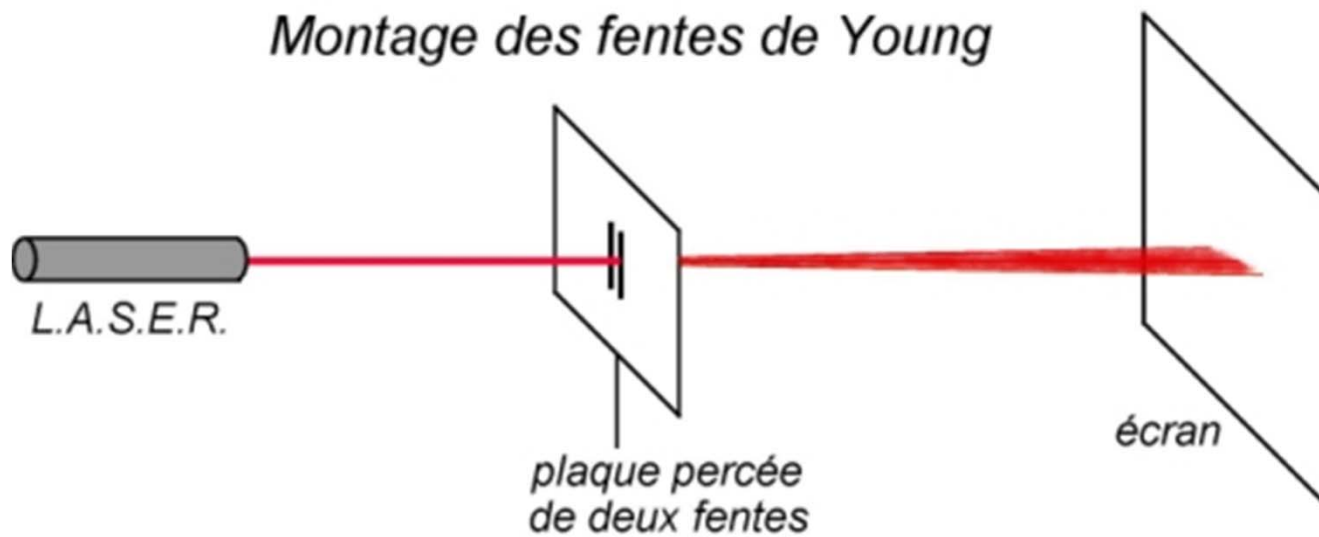
$$g/2 = \mathbf{1.001\ 159\ 652\ 182\ 79\ (10)}$$



Les bizarreries de la mécanique quantique



Une expérience en direct

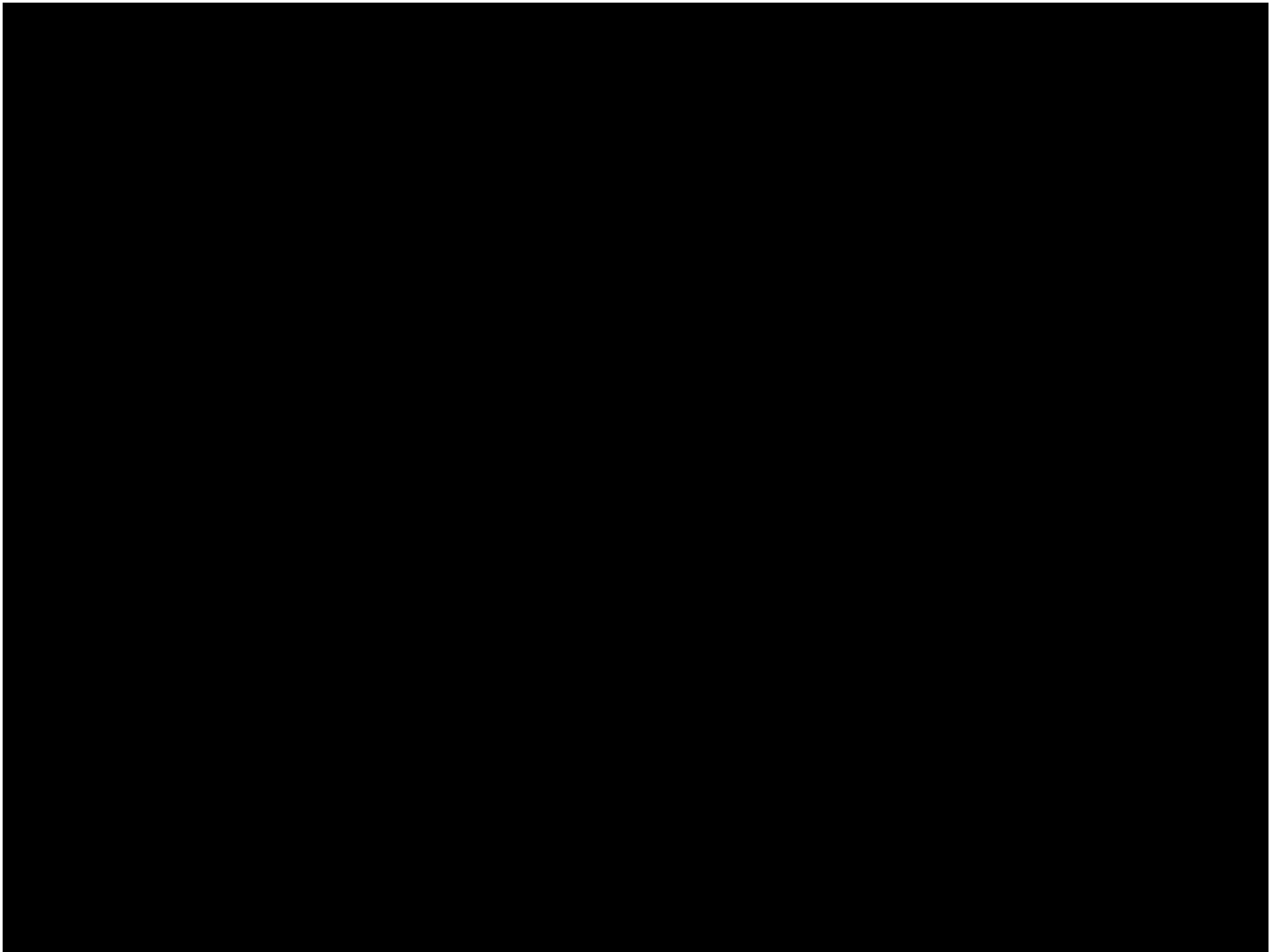


www.maxicours.com

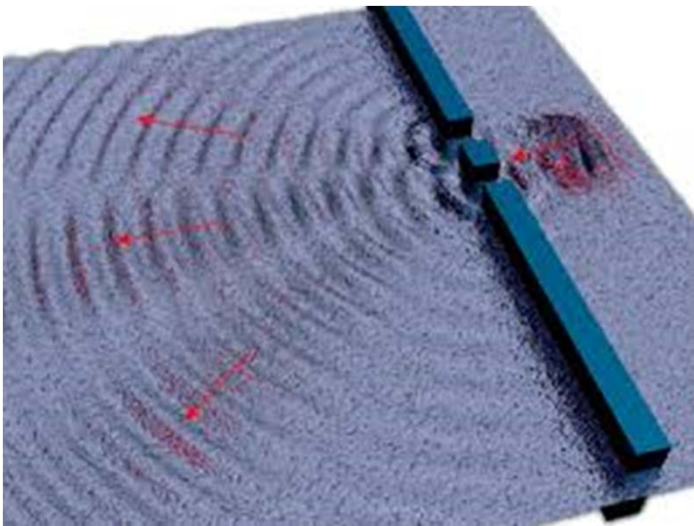
Espacement 0,5mm
Largeur 0,08mm



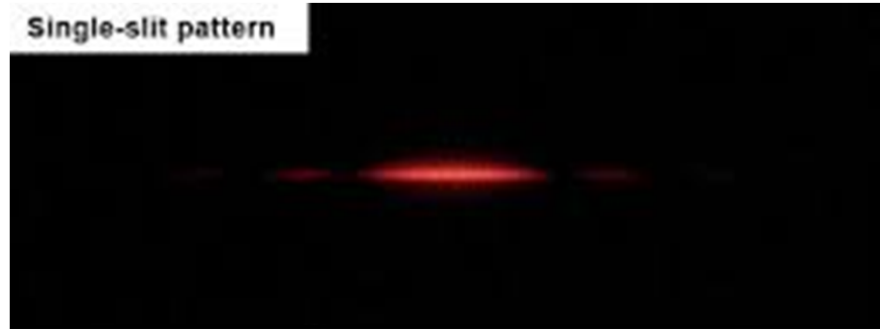
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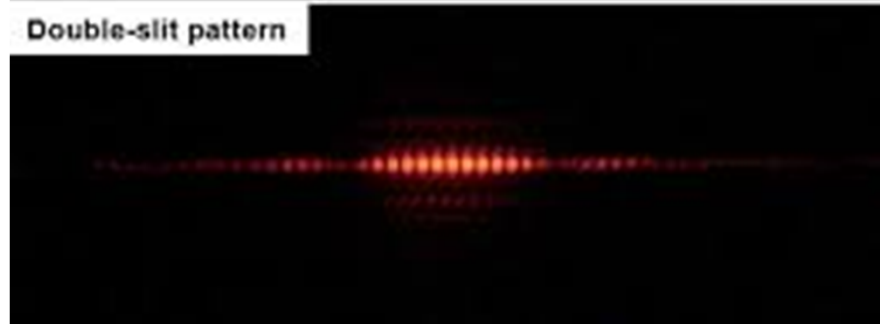
Onde



Single-slit pattern



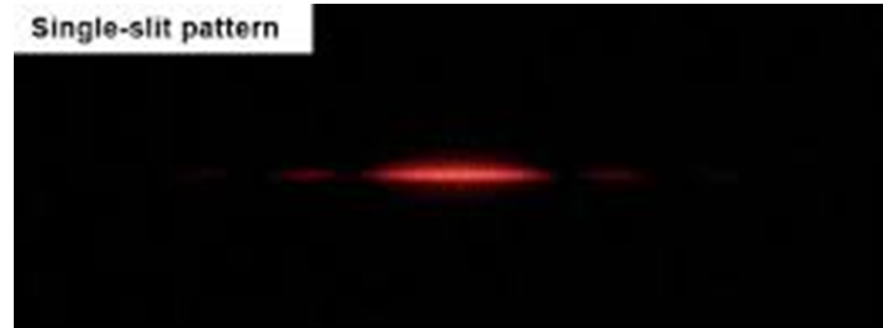
Double-slit pattern



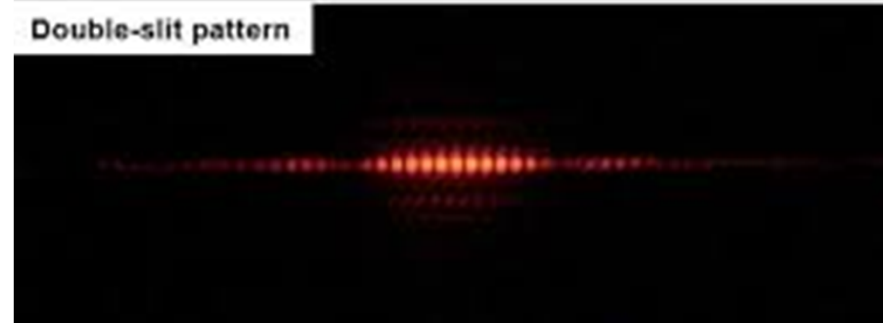
Le photon: une particule



Single-slit pattern



Double-slit pattern



À deux endroits à la fois

$$\Psi_T = \Psi_G + \Psi_D$$

$$\text{Probabilité} = \Psi_T^* \Psi_T$$

$$\Psi_T^* \Psi_T = \Psi_G^* \Psi_G + (\Psi_D^* \Psi_G + \Psi_G^* \Psi_D) + \Psi_D^* \Psi_D$$

Interférence



Le lien chimique



Intrication





Claude Bourbonnais



René Côté



Patrick Fournier



Ion Garate

Matériaux quantiques



Serge Jandl



Denis Morris



Jeffrey Quilliam



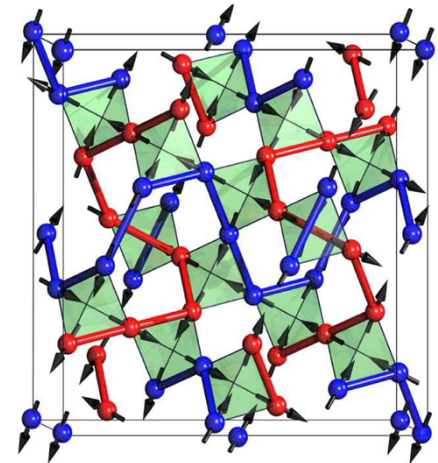
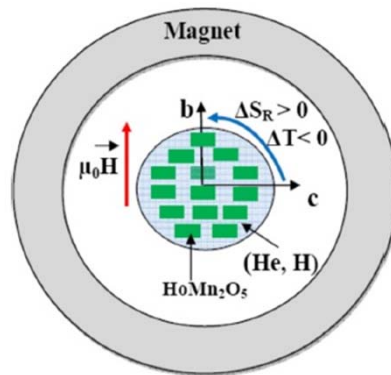
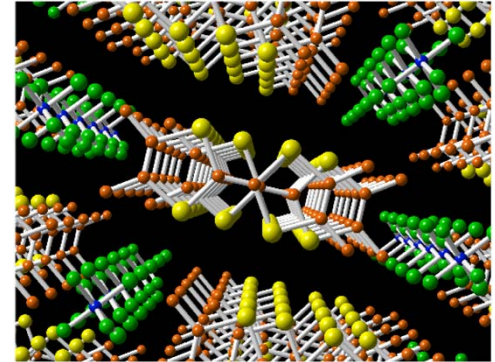
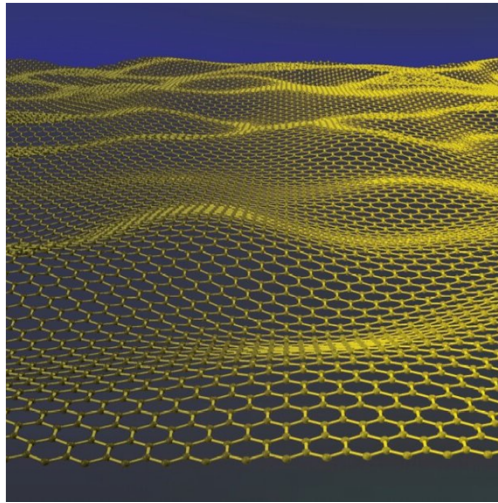
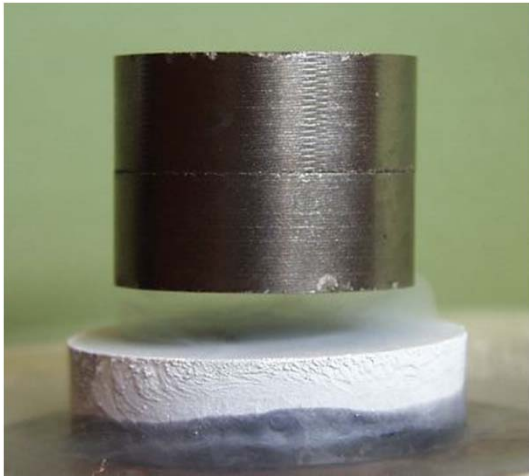
David Sénéchal



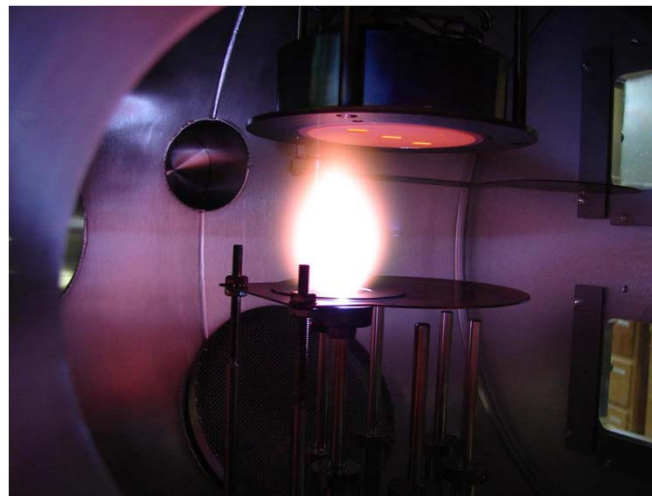
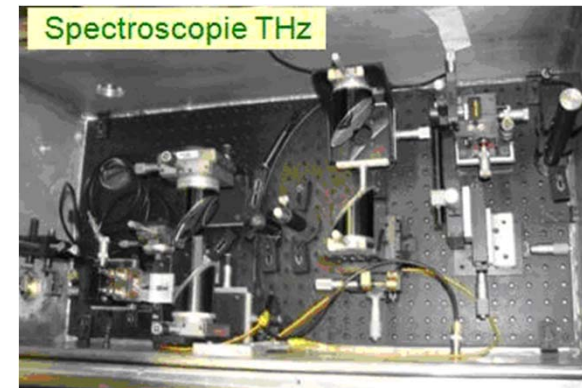
Louis Taillefer



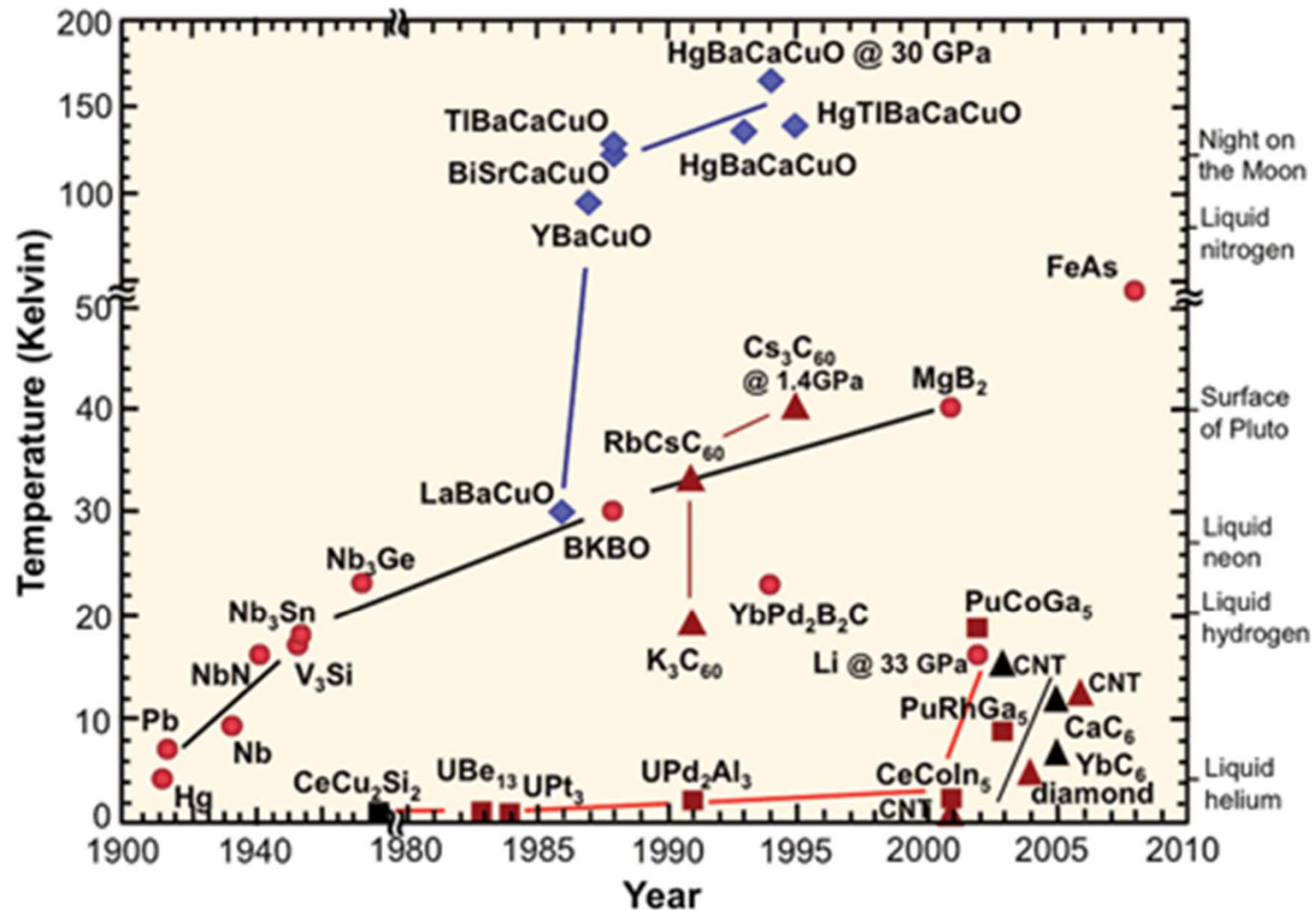
Quelques exemples



Des outils expérimentaux



Les supraconducteurs à haute température



Quel est le mécanisme de la supraconductivité à haute température?

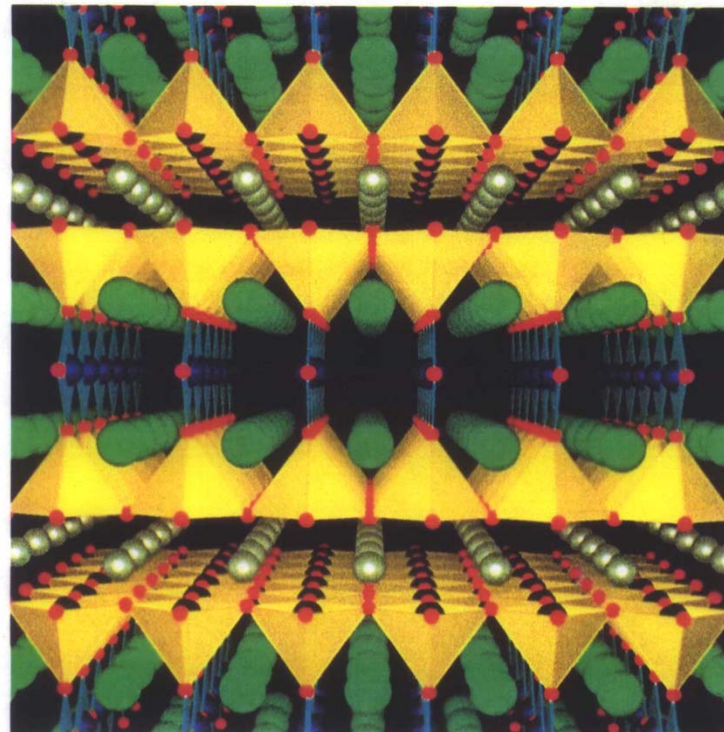
SCIENTIFIC AMERICAN

JUNE 1988
\$3.50

How nonsense is deleted from genetic messages.

R&D for economic growth: aggressive use of new technology.

Can particle physics test cosmology?



High-Temperature Superconductor belongs to a family of materials that exhibit exotic electronic properties.



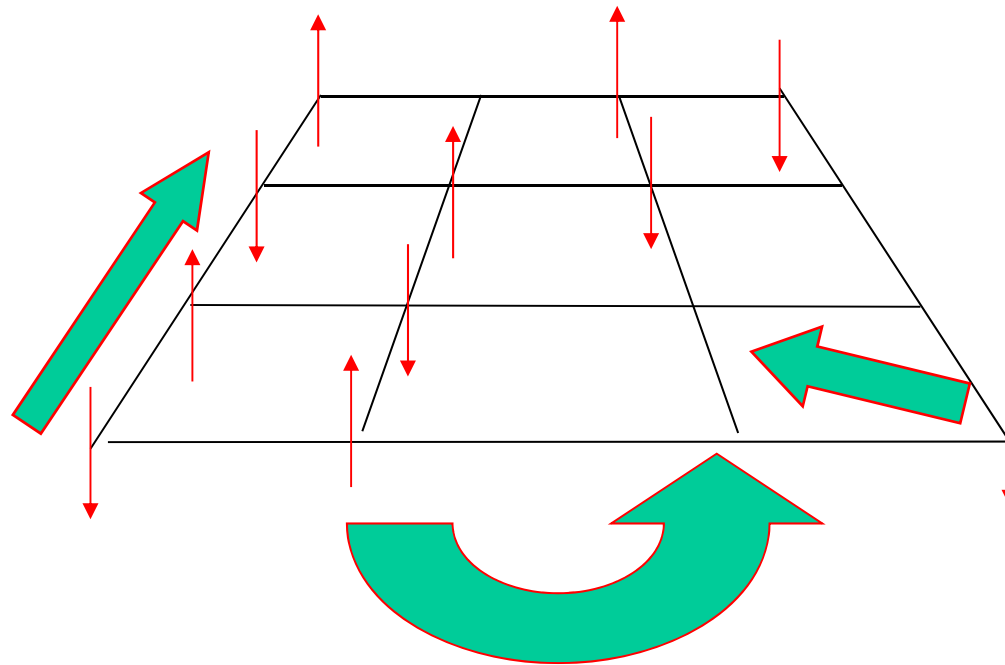
92-37

Localisé ou étendu?

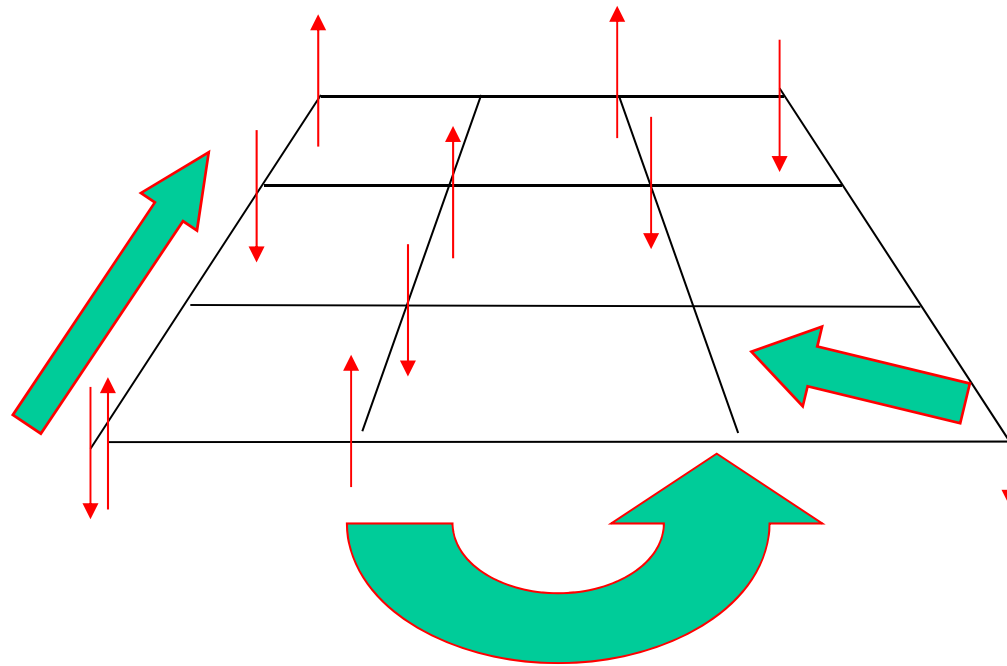


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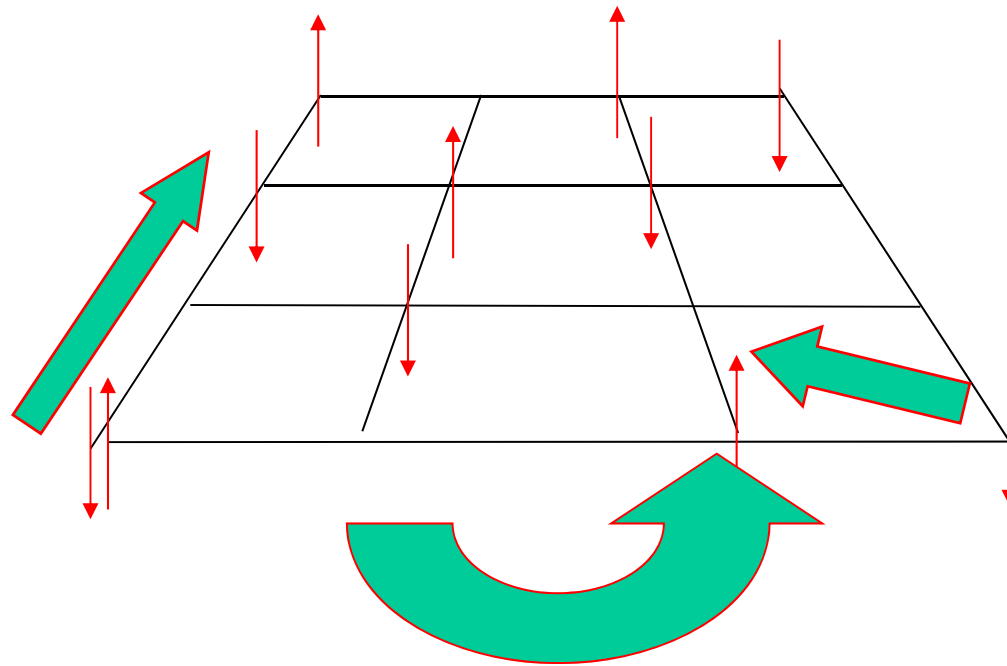
Pourquoi est-ce si difficile à comprendre?



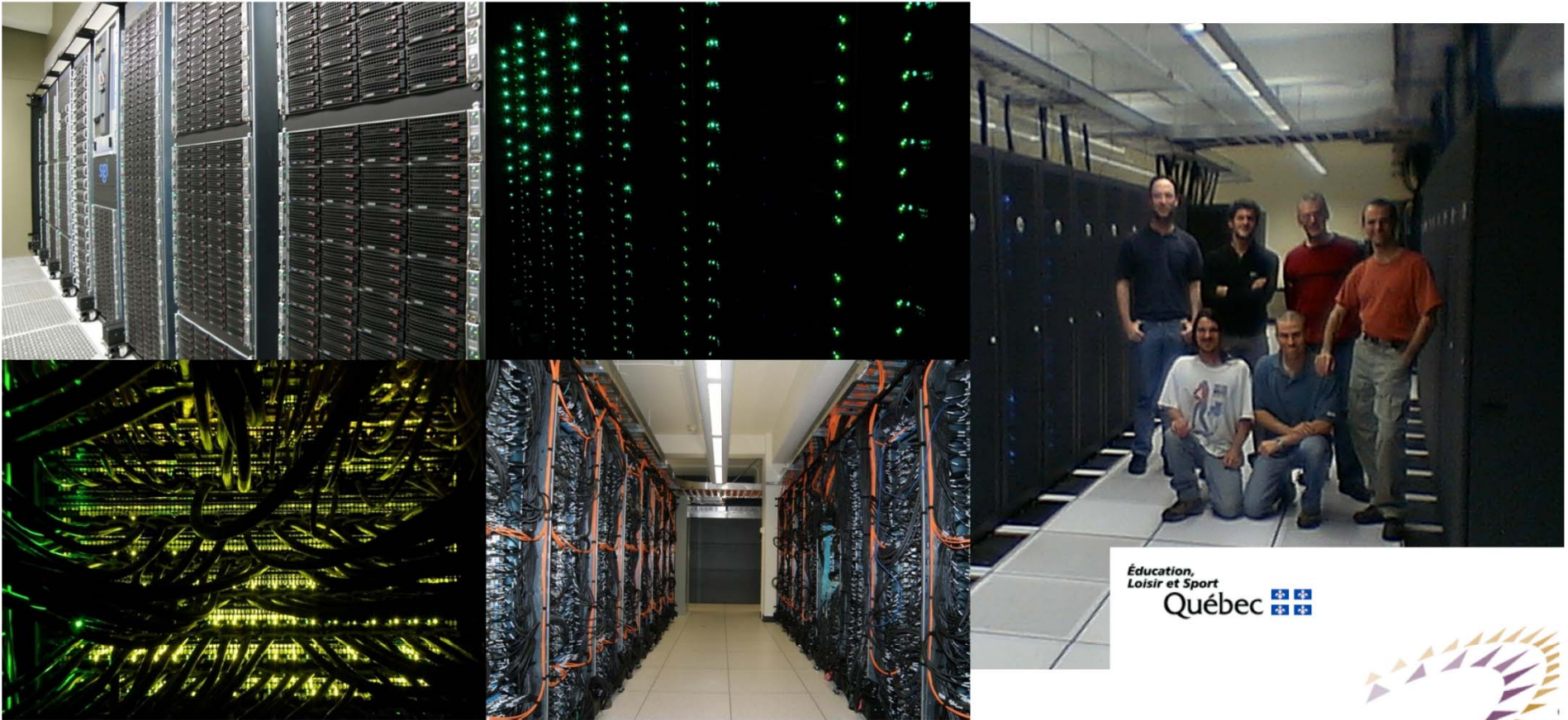
Pourquoi est-ce si difficile à comprendre?



Pourquoi est-ce si difficile à comprendre?



Un outil théorique puissant



Éducation,
Loisir et Sport
Québec



Canada Foundation for Innovation
Fondation canadienne pour l'innovation


Calcul Québec

 **compute + calcul**
CANADA

High Performance Computing

CREATING KNOWLEDGE
DRIVING INNOVATION
BUILDING THE DIGITAL ECONOMY

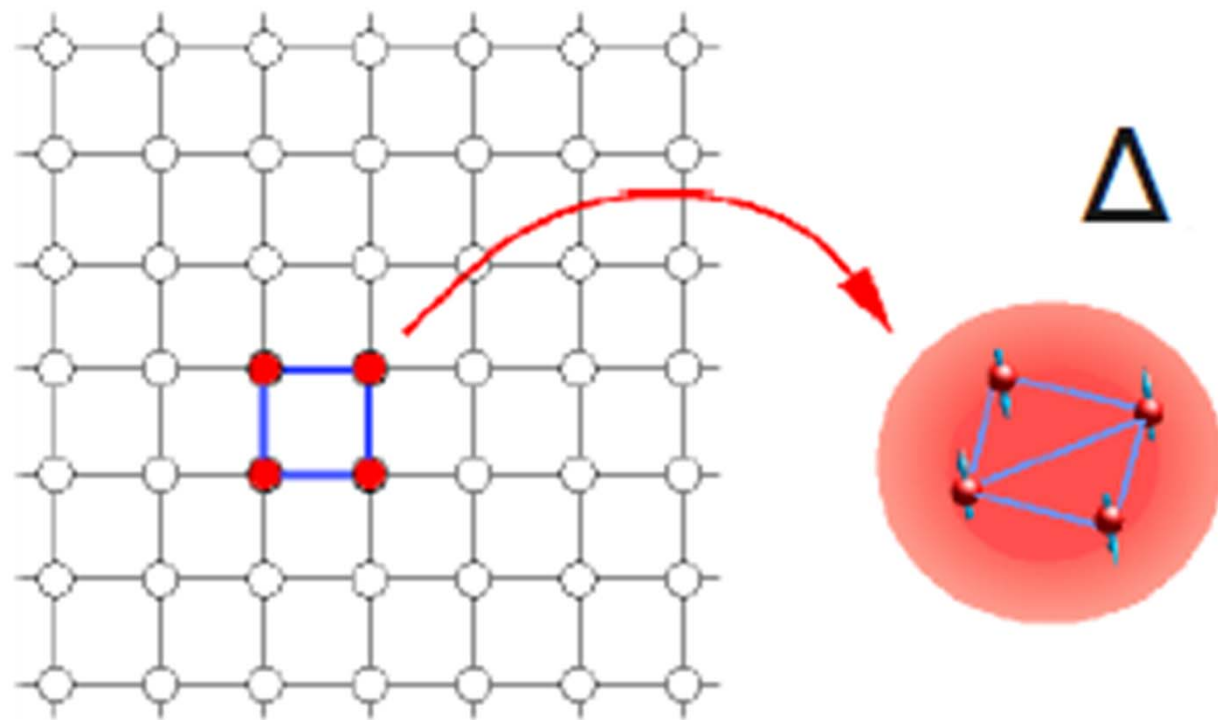
Le calcul de haute performance

CRÉER LE SAVOIR
ALIMENTER L'INNOVATION
BÂTIR L'ÉCONOMIE NUMÉRIQUE

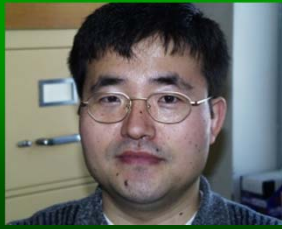


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Des approches qui incluent à la fois l'aspect onde et particule



Georges, Kotliar, Jarrel, 1992 (Metzner, Vollhardt)



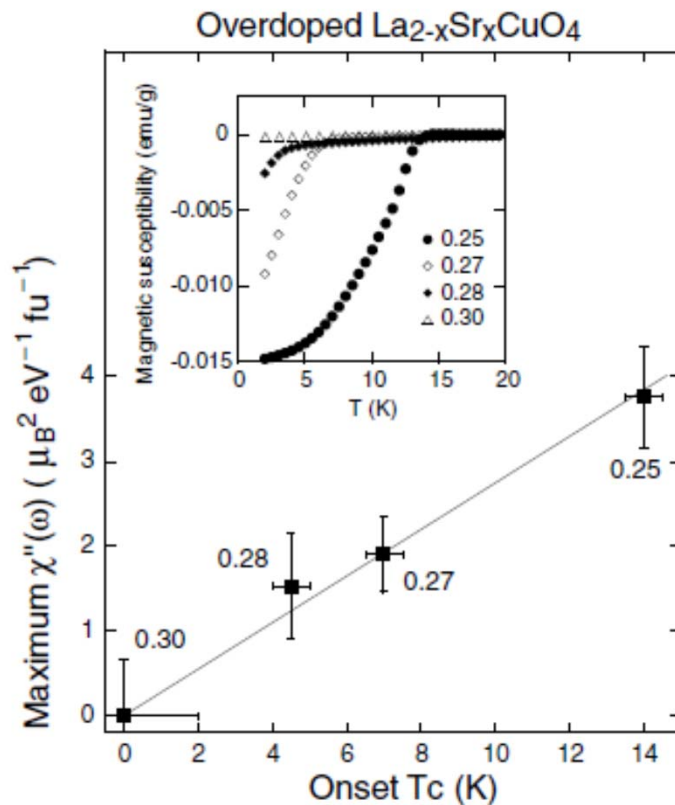
Mécanisme magnétique



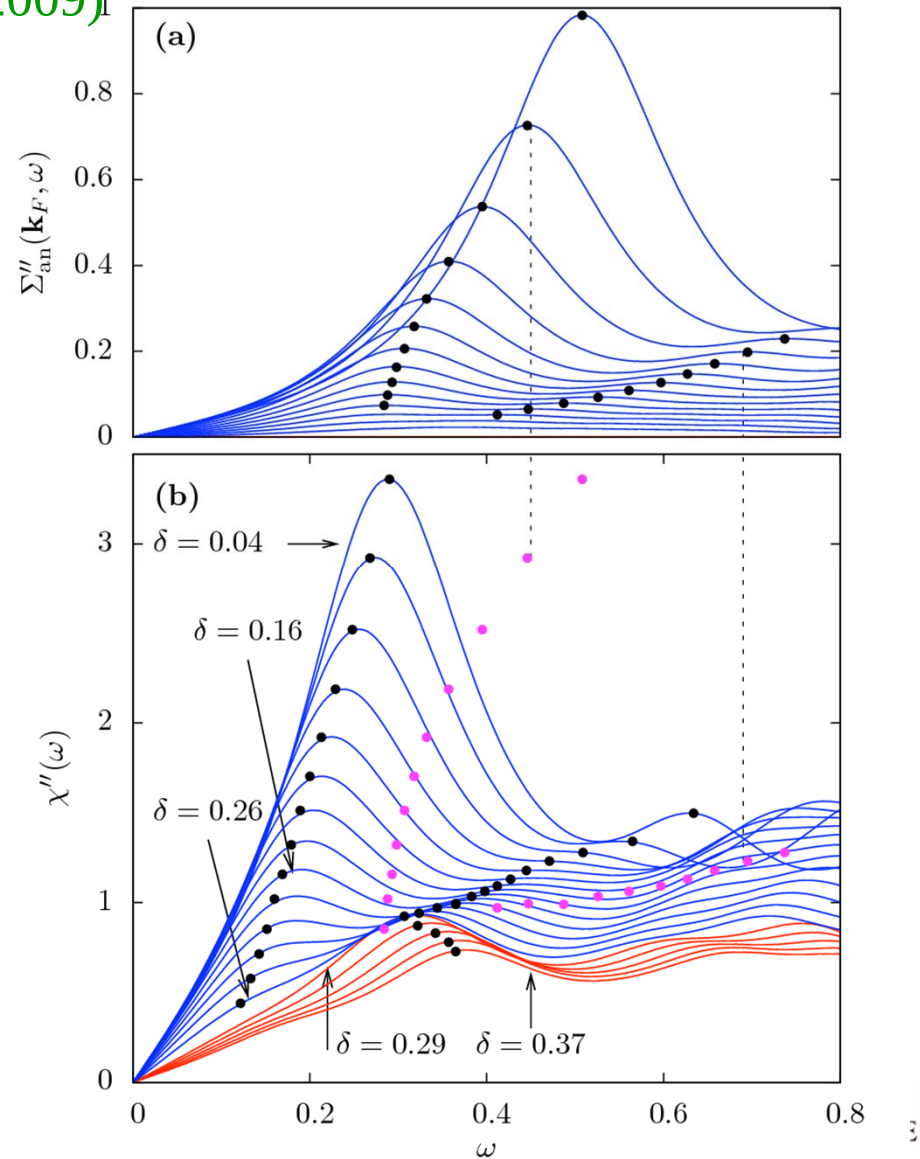
Kyung, Sénéchal, AMST PRB **80**, 205109 (2009)

Civelli, PRL + PRB 79 195113 (2009)

Gull and Millis arXiv:1407.0704



Wakimoto ... Birgeneau
PRL (2004)



Des nouveaux concepts et des algorithmes de plus en plus performants

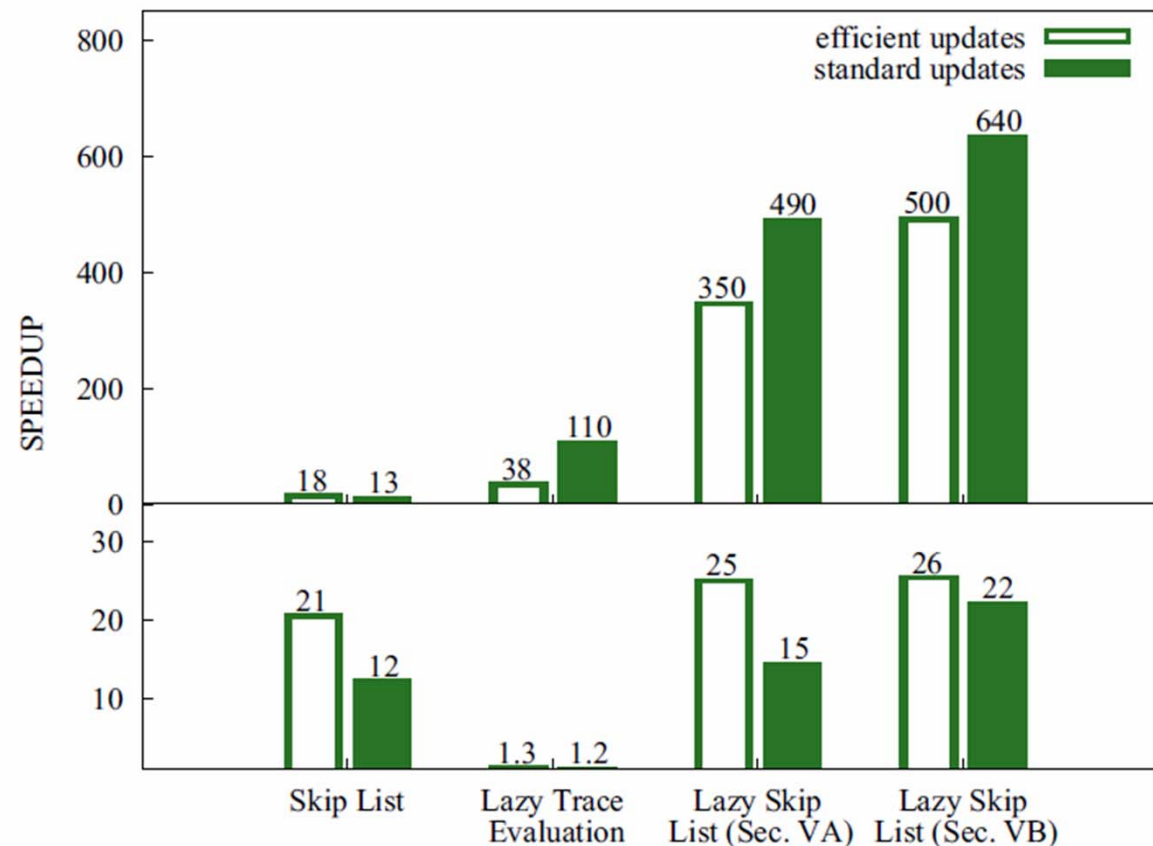


FIG. 1. (Color online) Benchmark of different optimizations presented in this paper on the basis of a LNO thin film simulation [27] (top panel) and a FeTe simulation (lower panel), using standard updates

Sémon et al. PRB **90**, 075149 (2014)



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Une deuxième révolution technologique



Un avertissement

- Popular Mechanics, 1949
- Alors qu'un calculateur comme l'ENIAC est équipé de 18,000 lampes à vide et pèse 30 tonnes, les ordinateurs de l'avenir n'auront probablement que 1,000 lampes à vide et ne pèseront peut-être qu'une tonne et demi.



Et le rêve



room-temperature superconductors

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 (previ-

ous 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.

SCIENTIFIC AMERICAN 43

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



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Transport des personnes



Maglev, aéroport de Shangai



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



Test, lévitation magnétique, Japan Rail



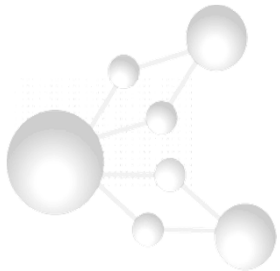
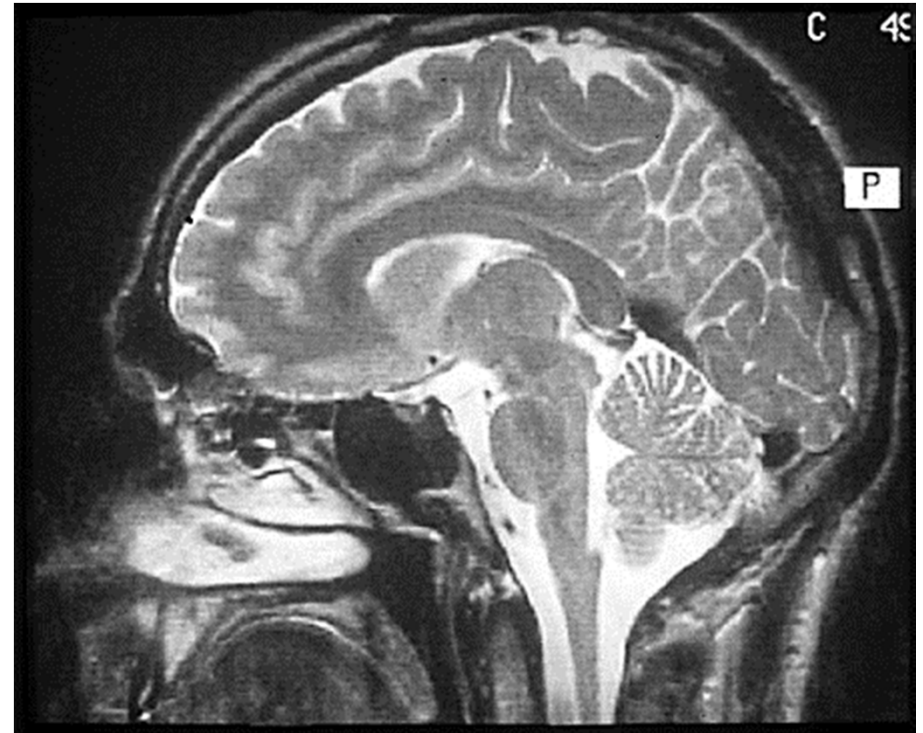
JR-MLX01 maglev train at [Yamanashi](#) test track



Applications médicales



Imagerie par résonance magnétique



Recherche : 1) Plus hauts champs
2) Autre façon de détecter (SQUID)

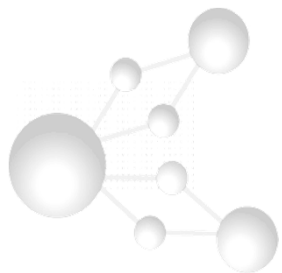
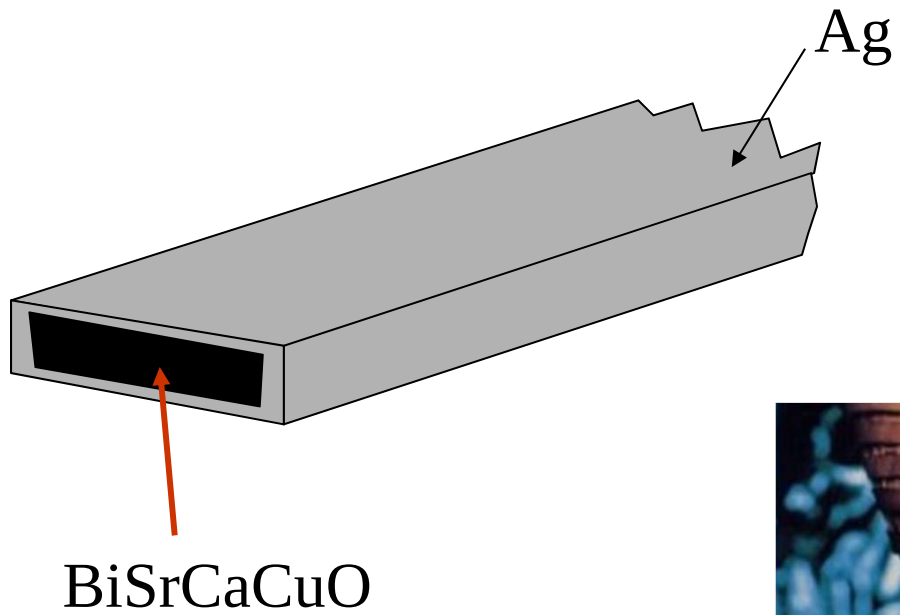


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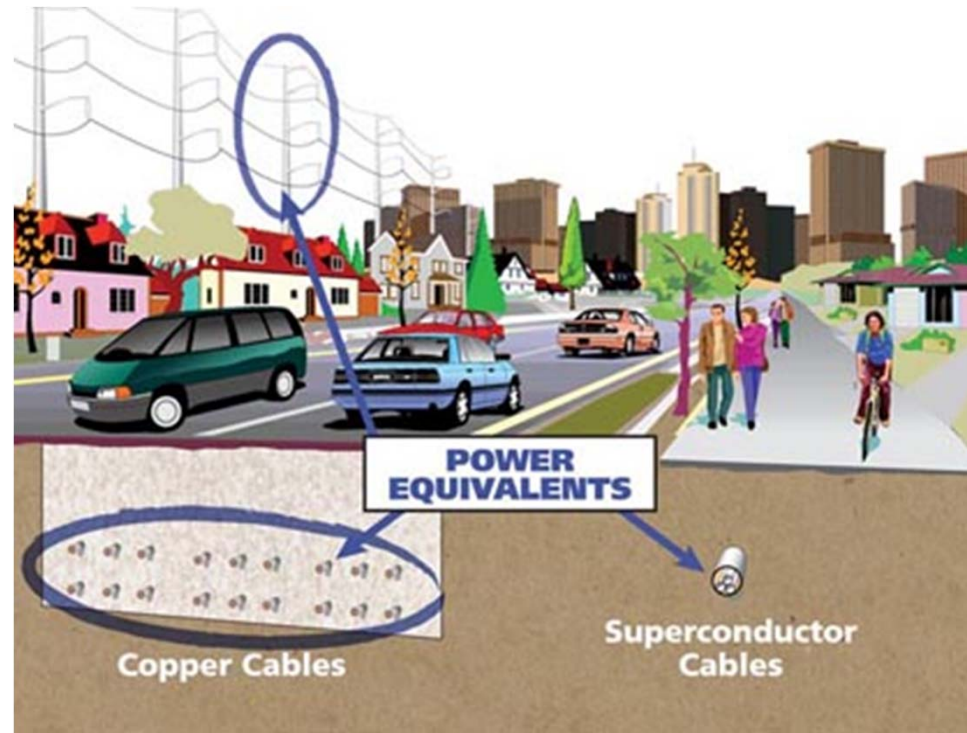
Transport d'énergie



Lignes à transmission



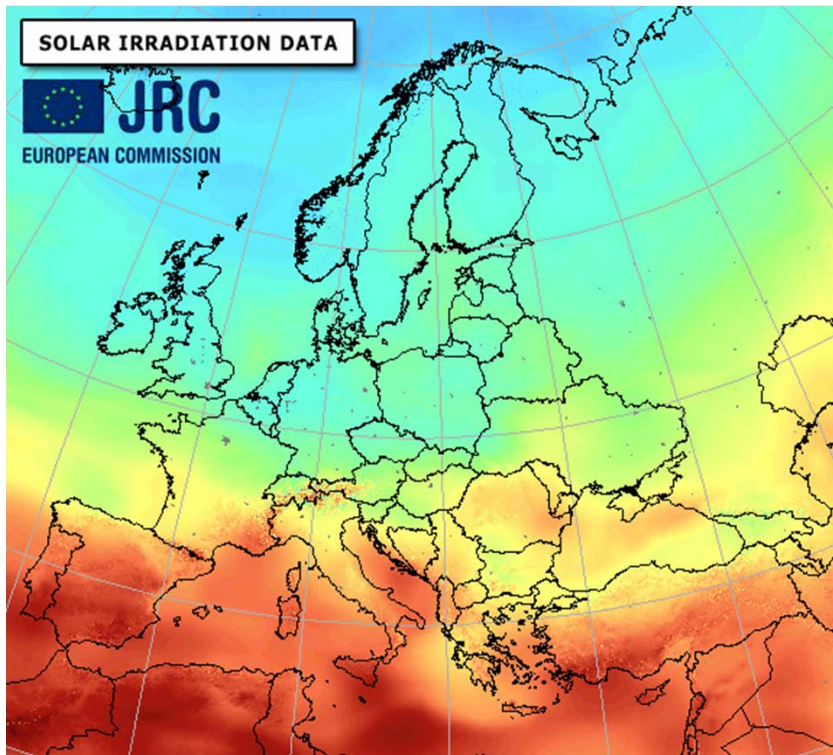
7 octobre 2010, American Superconductors



3,000 km de câbles supraconducteurs pour la Corée du sud



Génération et besoin



<http://www.ssb-foundation.com/members.html>



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Génération et câbles supraconducteurs

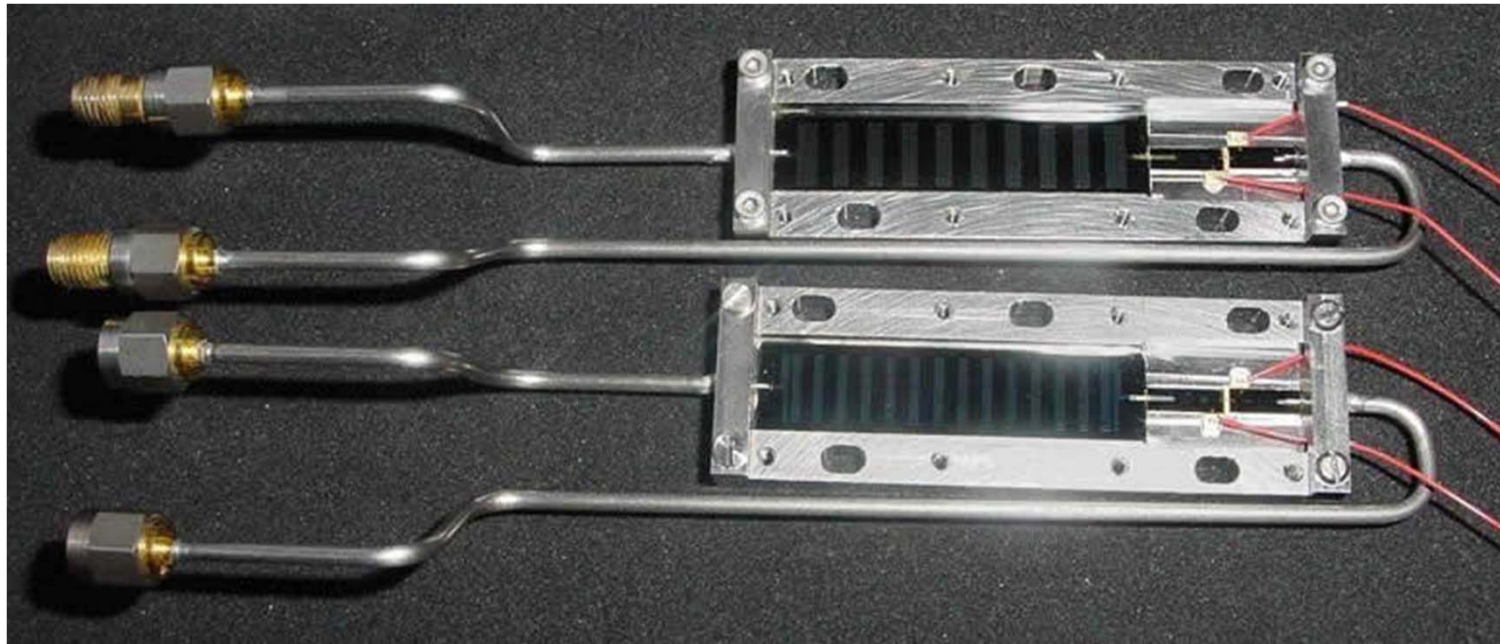
- Deuxième forum économique Japon-Arabe en décembre 2010, Tunisie et Japon ont signé des accords pour travailler à un projet de cette nature.
- Projet pilote 5MW.
- Hideomi Koinuma Université de Tokyo: Objectif 100GW (50% du total) + surgénération



Et dans toutes sortes de secteurs



Téléphonie cellulaire



améliorer leur performance.

http://findarticles.com/p/articles/mi_m0EIN/is_1999_Feb_8/ai_53731854/

www.supraconductivite.fr



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Materials Genome Initiative



Materials Genome Initiative

[About](#) | [Goals](#) | [Examples](#) | [News & Announcements](#) | [Federal Programs](#) | [External Stakeholder Activities](#) | [Contact Us](#)



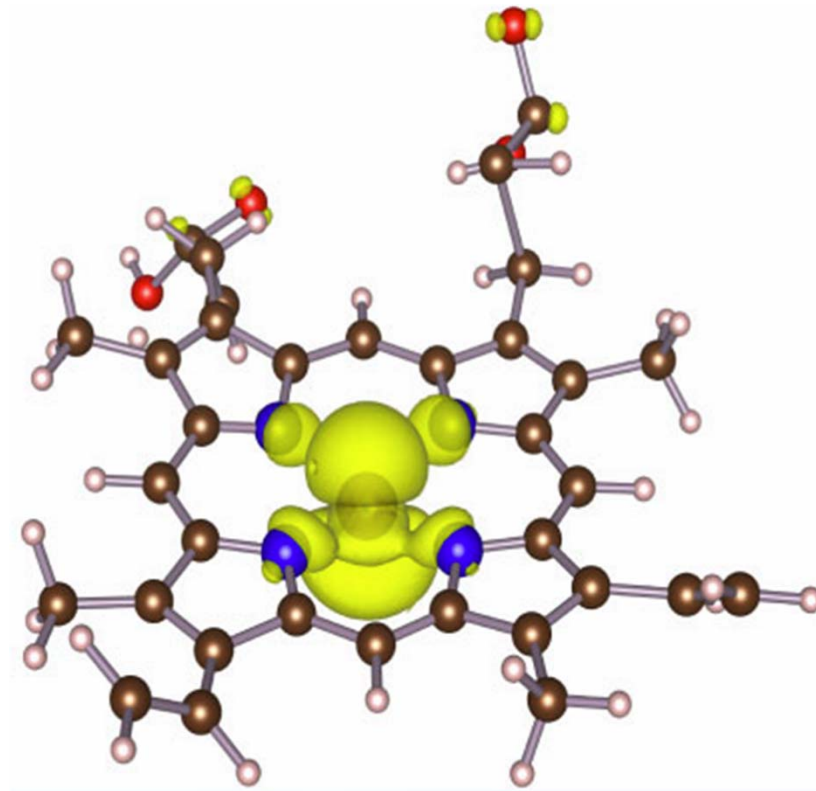
To help businesses discover, develop, and deploy new materials twice as fast, we're launching what we call the Materials Genome Initiative. The invention of silicon circuits and lithium-ion batteries made computers and iPods and iPads possible -- but it took years to get those technologies from the drawing board to the marketplace. We can do it faster."

-President Barack Obama, June 2011



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Matériaux quantiques en biologie



Weber et al. PRL **110**, 106402 (2013)





Alexandre Blais



Michel Pioro-Ladrière

L'ordinateur quantique



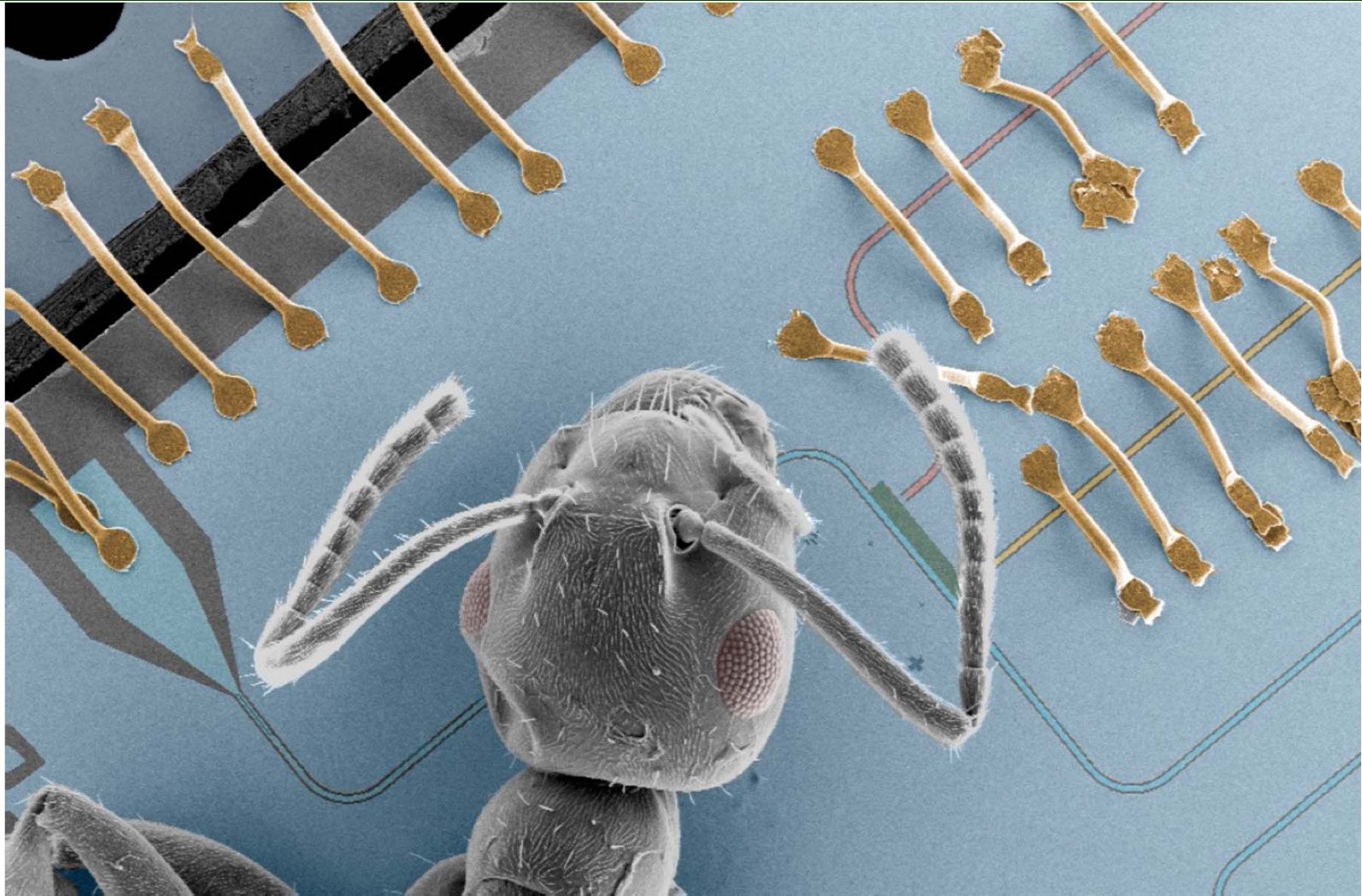
David Poulin



Bertrand Reulet



Circuits quantiques supraconducteurs



Quantum Device Lab, ETH Zurich



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L'ordinateur quantique

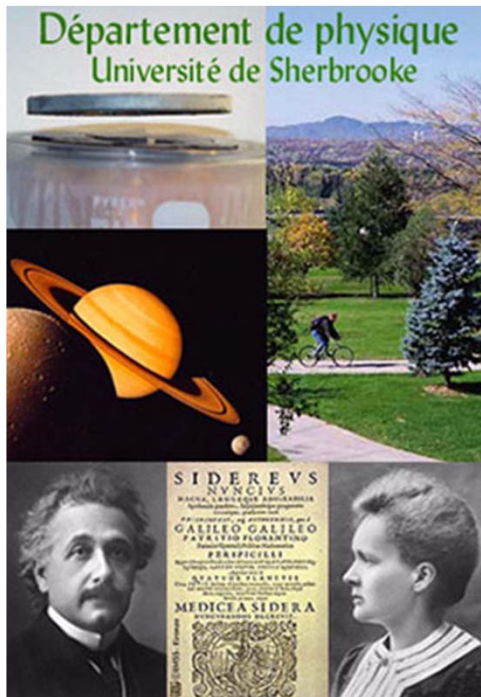


Edward Bellamy (USA) 1887

- 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'homme et nous pourrions cesser de chercher des améliorations.



André-Marie Tremblay



Le regroupement québécois sur les matériaux de pointe



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Merci