Structure of Matter
The Solid State

WS 2013/14

Lectures (Tuesday & Friday)

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www.ph2.uni-koeln.de
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Last time:

Semiconductor devices

Today:

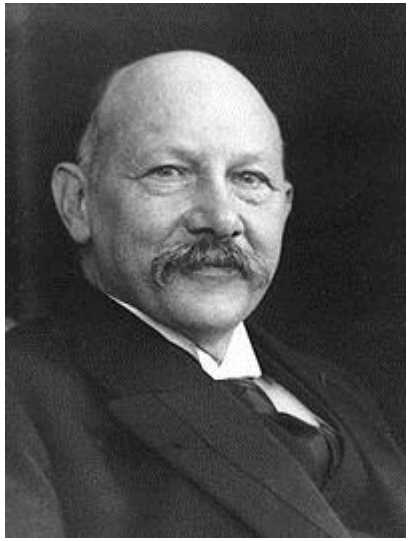
Superconductivity

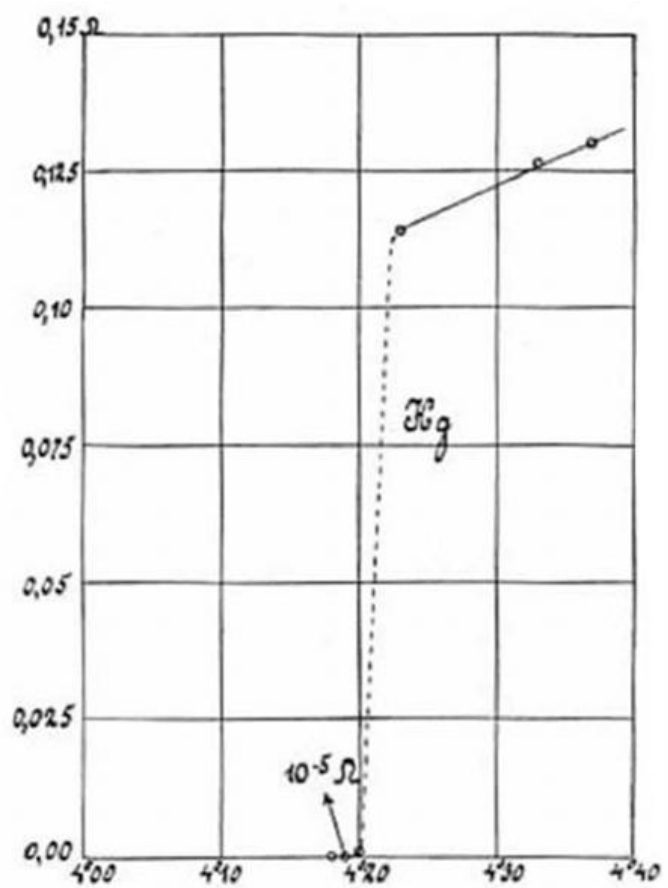
Your questions

Superconductivity

1911, Leiden
Discovery of
Superconductivity

1912: disappears
at high currents or
applied magn. fields

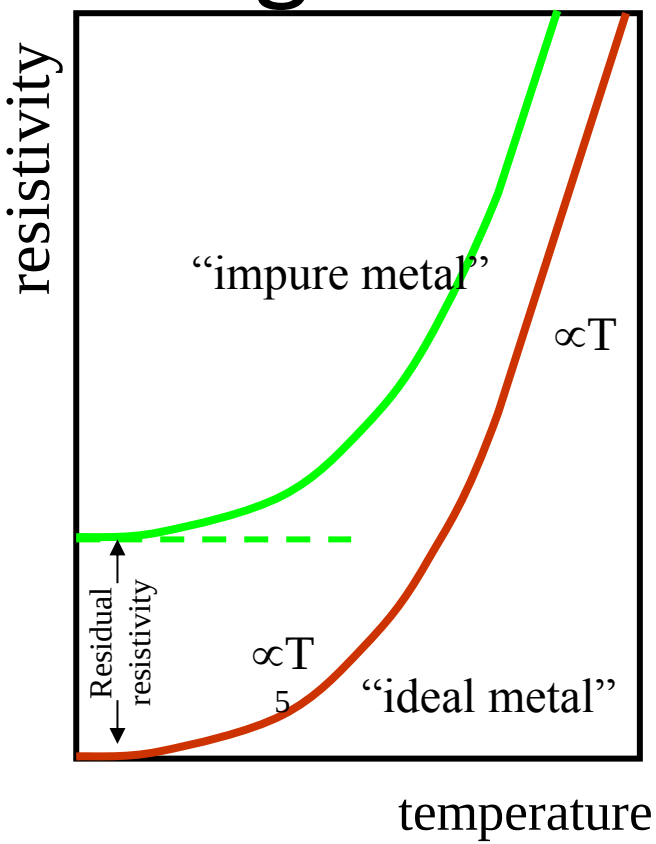




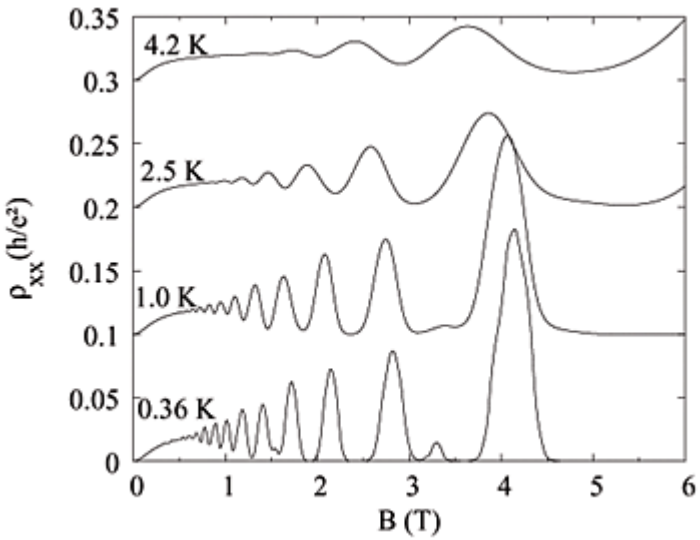
Heike Kamerlingh Onnes
Nobel prize 1913 (Low T research including liquid He)
PhD RUG on ‘new proof for the rotation of the earth’

Is zero resistance enough?

Ideal metal has zero resistance at T=0K
(no xtal imperfections, impurities
or phonons)



Also in shubnikov-de haas effect
Zero resistance (no scattering possible)

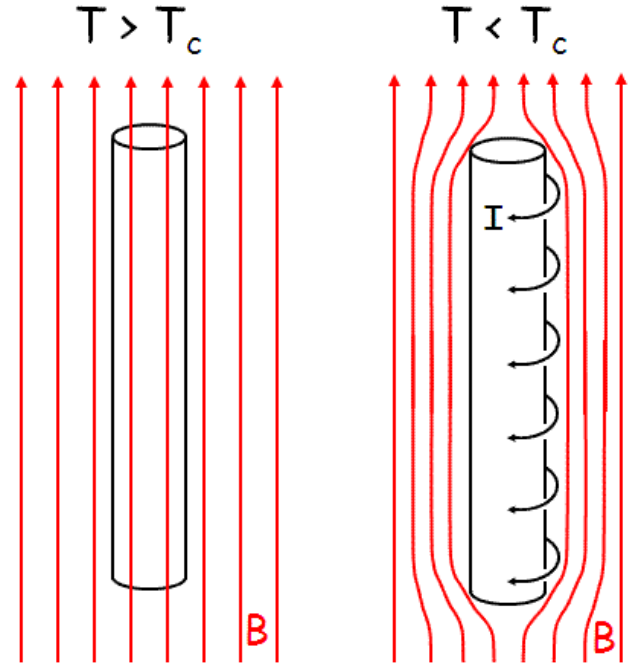


GaAs/AlGaAs
Heterostructure

J. P. Freire et al, Braz. J. Phys. **34** (2004)

Meissner Ochsenfeld effect (1933)

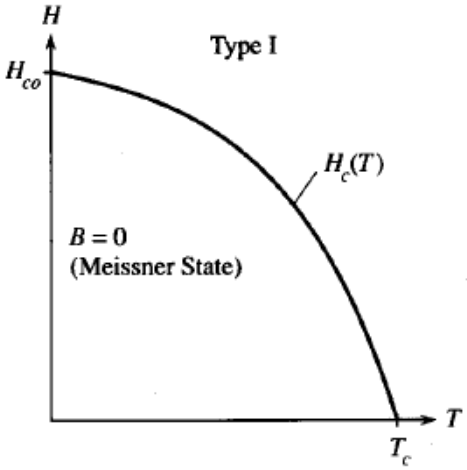
Superconductor is also a perfect diamagnet.

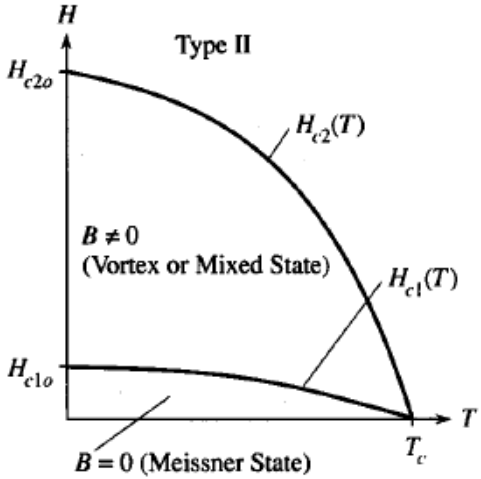


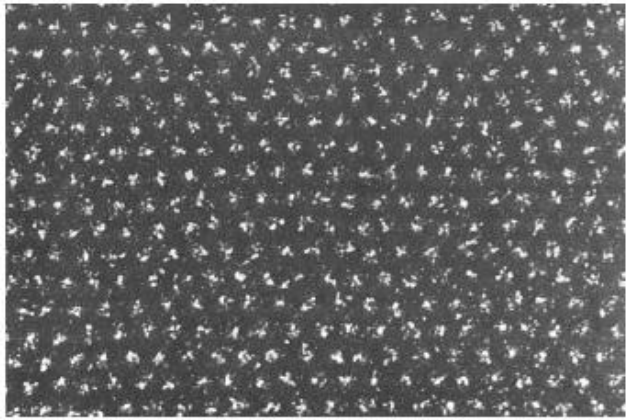
Type I and II

Type I: destruction of superconductivity upon applied magnetic field by first order phase transition

Type II: At first critical field: flux penetration, superconductivity destroyed at second critical field





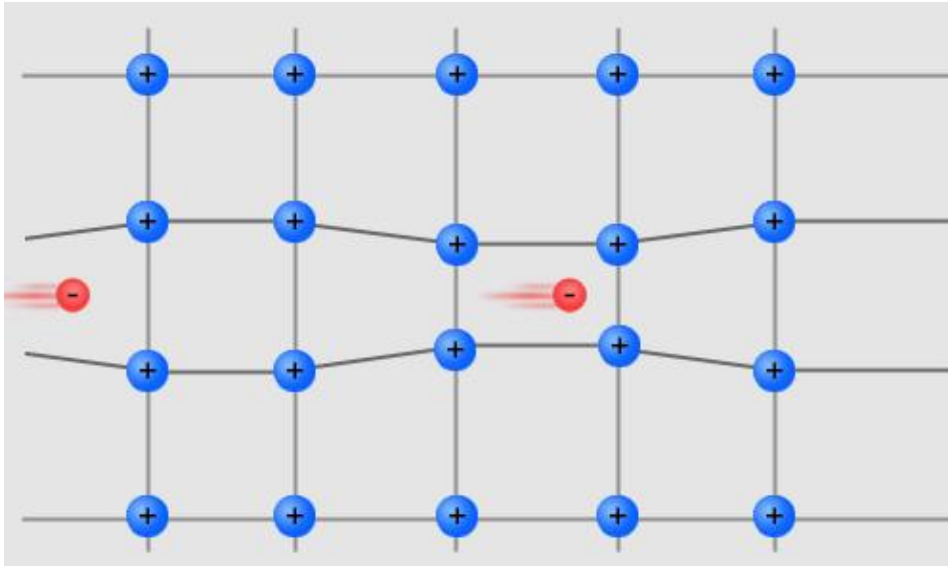


YBCO vortex state (decorated)

BCS Theory (1957)

Bardeen, Cooper & Schrieffer: condensation of Cooper pairs

Electrons 'bind' together through lattice polarization
→ bosons → condensation → energy gap for excitations



Nobel prize 1974

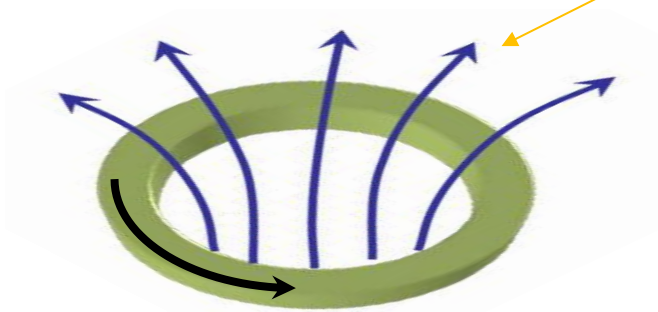
Flux quantization

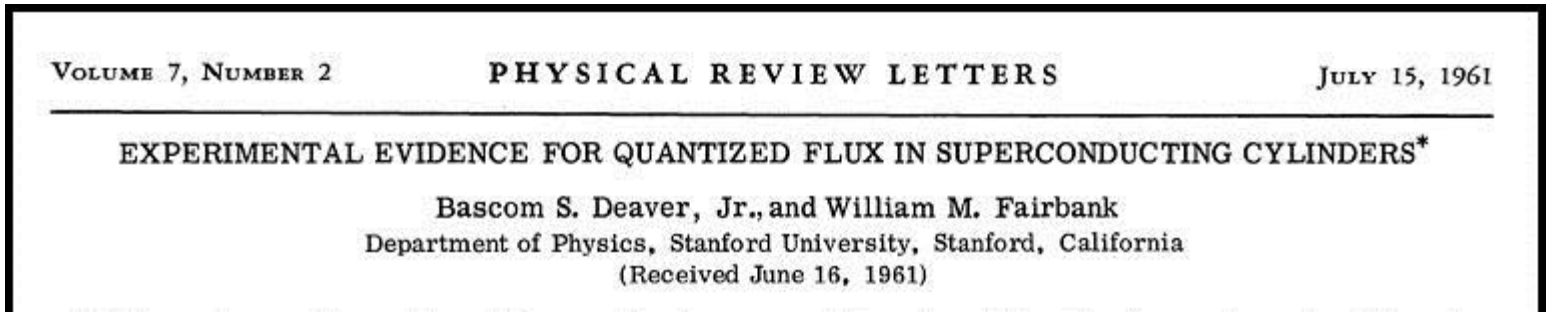
$$\Phi = \int \vec{B} \cdot d\vec{A} = n\varphi_0$$

Earth's magnetic field ~ 500 mG, so in 1 cm^2 of $\mathbf{B}_{\text{Earth}}$ there are ~ 2 million φ_0's.

$$\varphi_0 = \frac{h}{2e} \sim 2\times10^{-15}\ \mathrm{V\cdot s}$$

Total flux (field*area) Φ is integer multiple of ϕ_0



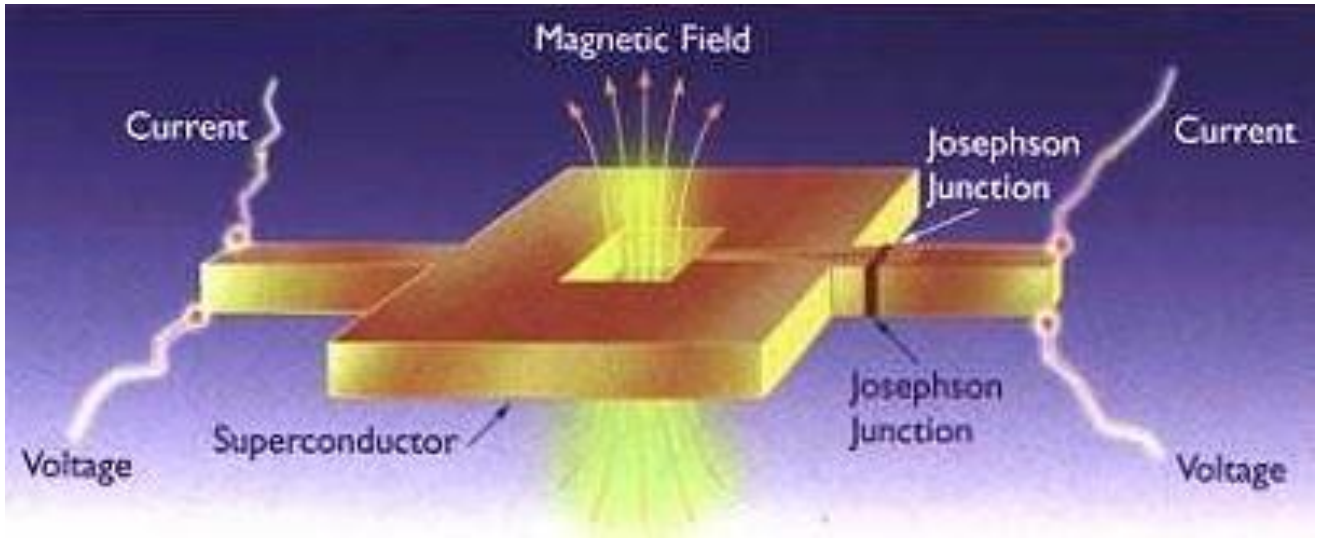


VOLUME 7, NUMBER 2 PHYSICAL REVIEW LETTERS JULY 15, 1961

EXPERIMENTAL EVIDENCE FOR QUANTIZED FLUX IN SUPERCONDUCTING CYLINDERS*

Bascom S. Deaver, Jr., and William M. Fairbank
Department of Physics, Stanford University, Stanford, California
(Received June 16, 1961)

SQUID



$$\Delta\varphi(B) + \Delta\varphi(I) = n \cdot 2\pi$$

1986, start of a new era on superconductivity

Z. Phys. B – Condensed Matter 64, 189–193 (1986)

Condensed Matter
Zeitschrift für Physik B

Retraction offer to Joe Eck
001785 263 0166 Springer

Possible High T_c Superconductivity in the Ba – La – Cu – O System

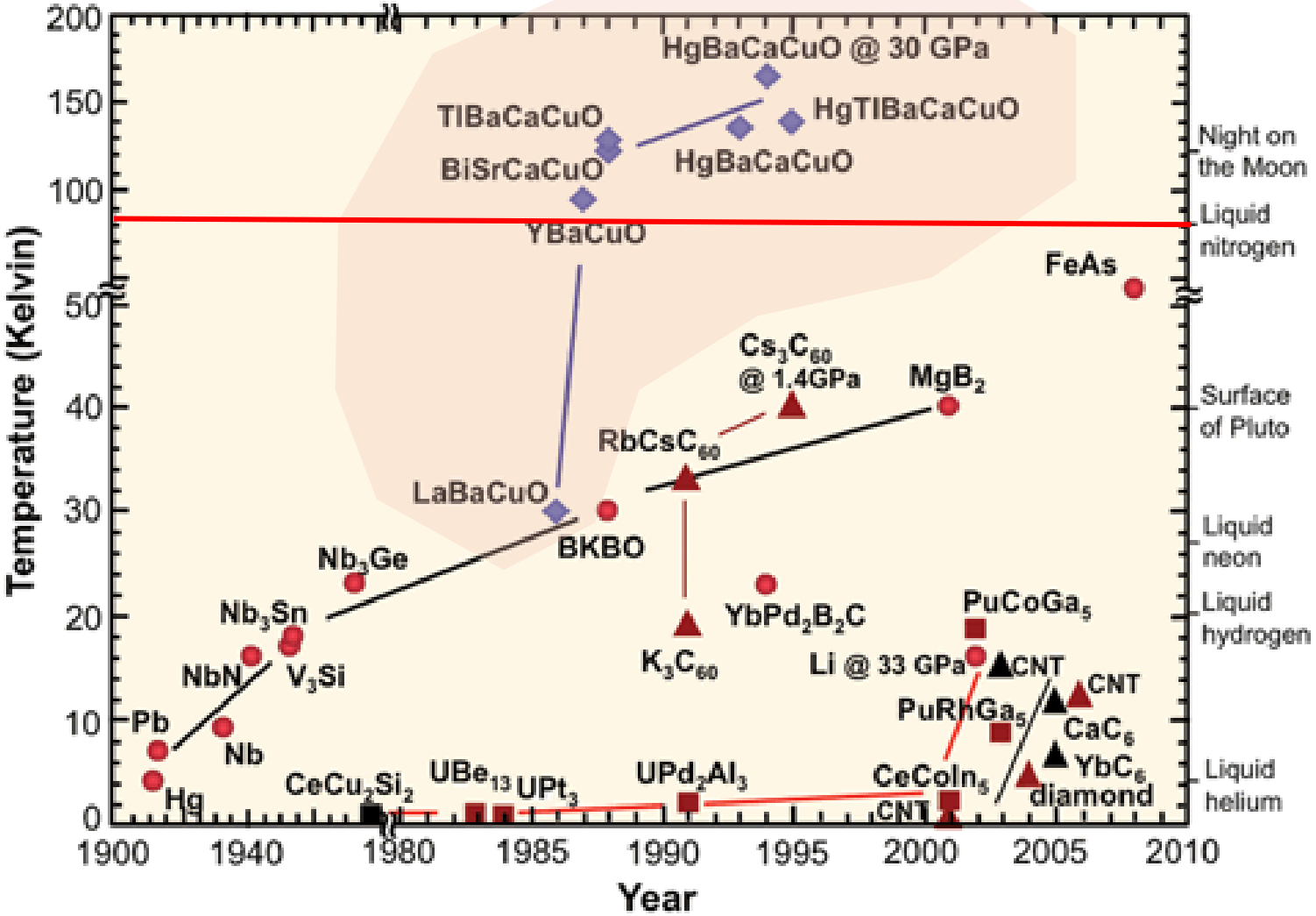
Martin Ahg

J.G. Bednorz and K.A. Müller
IBM Zürich Research Laboratory, Rüschlikon, Switzerland

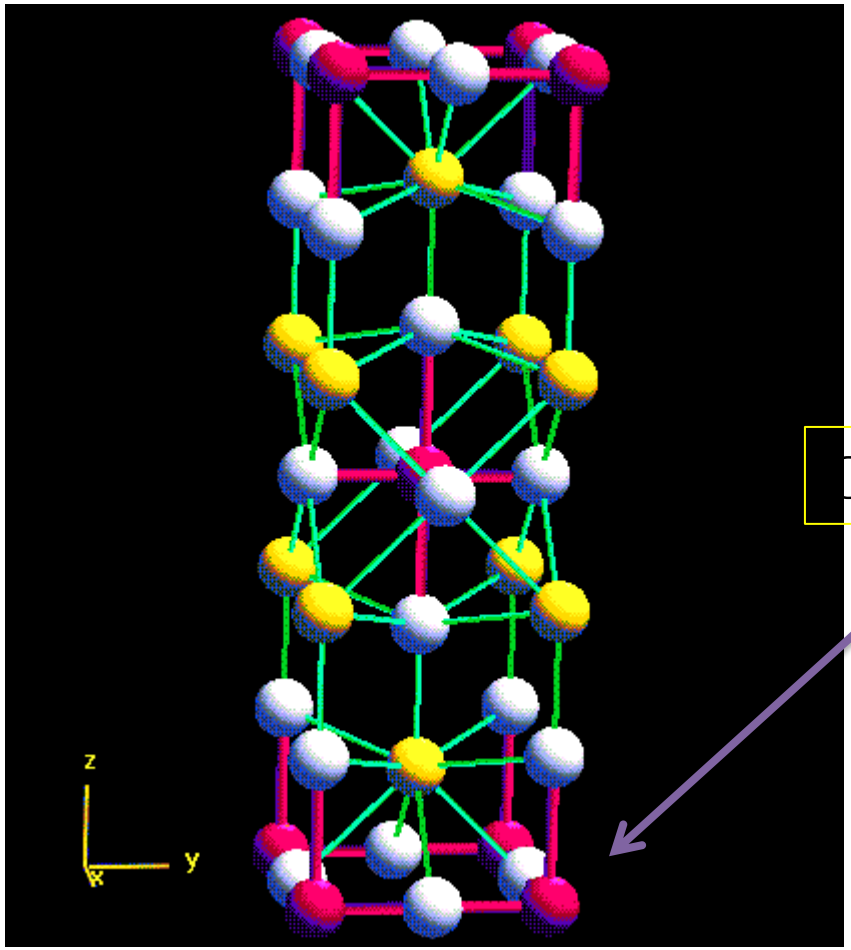
Received April 17, 1986

Bednorz & Muller, nobel prize 1987

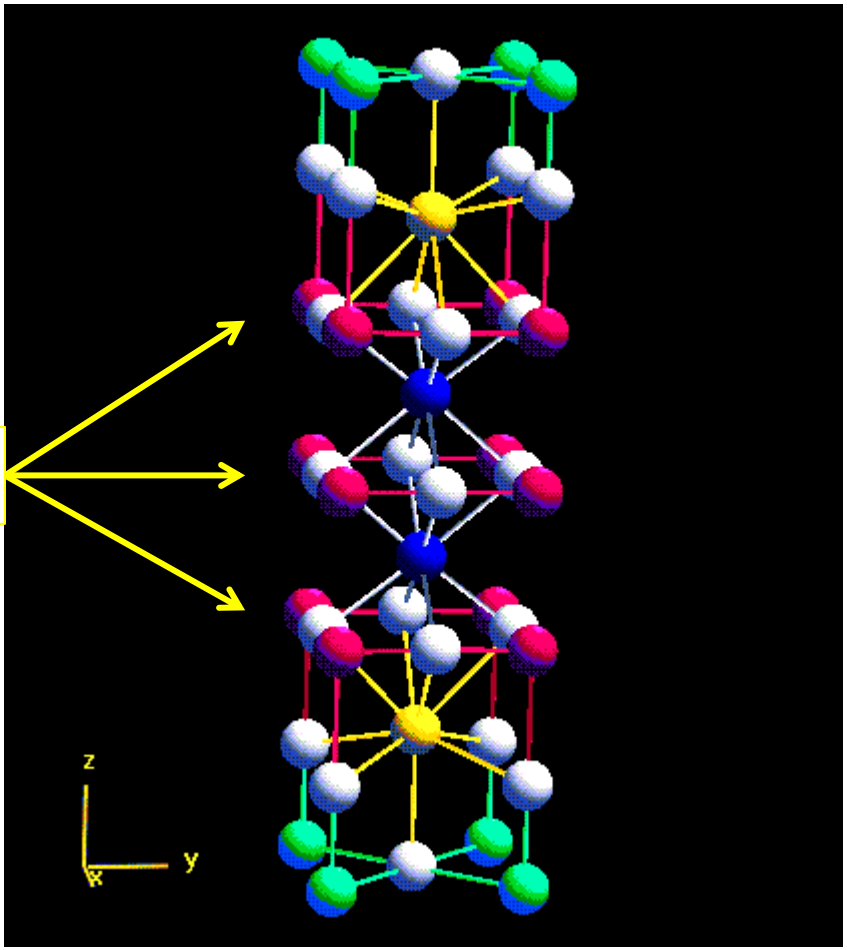
High Tc superconductors



The perovskite superconductors



CuO planes



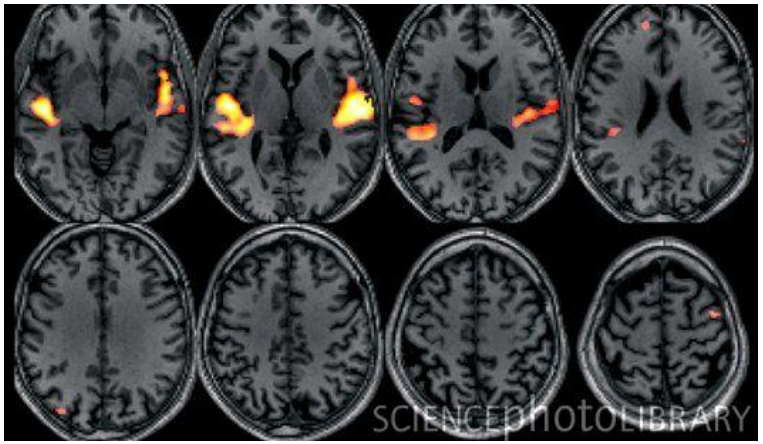
$(La,Ba)_2CuO_4$ (T_c=38 K)

$TlBa_2Ca_2Cu_3O_{9+d}$ (T_c=123 K)

Applications

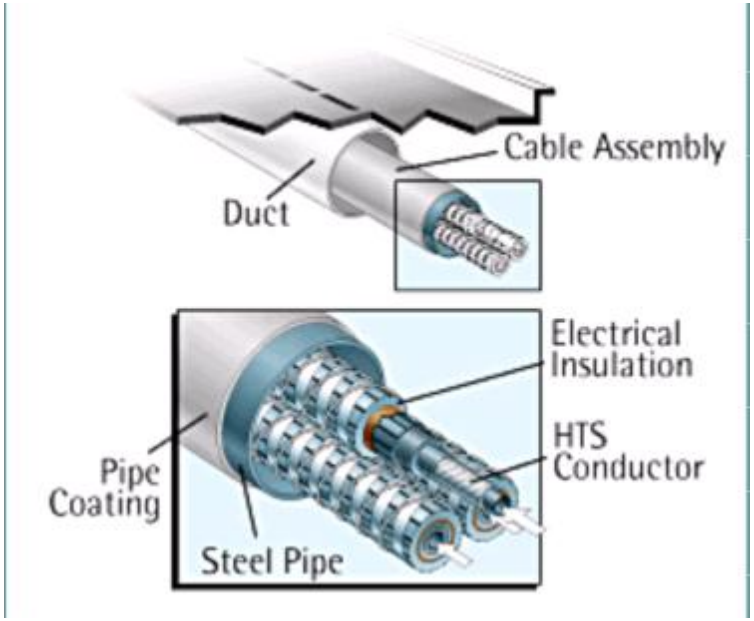
Yamanashi XML01 train
581 km/h

Medical imaging (soft tissue, MRI)



Applications

Telecommunication filters



Power transmission lines

Accelerators