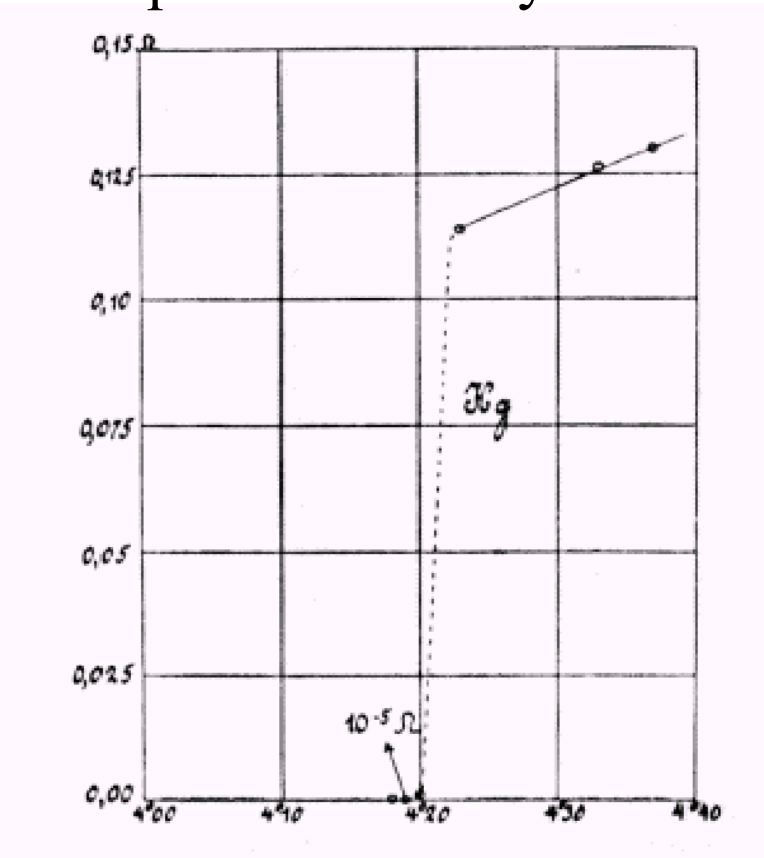
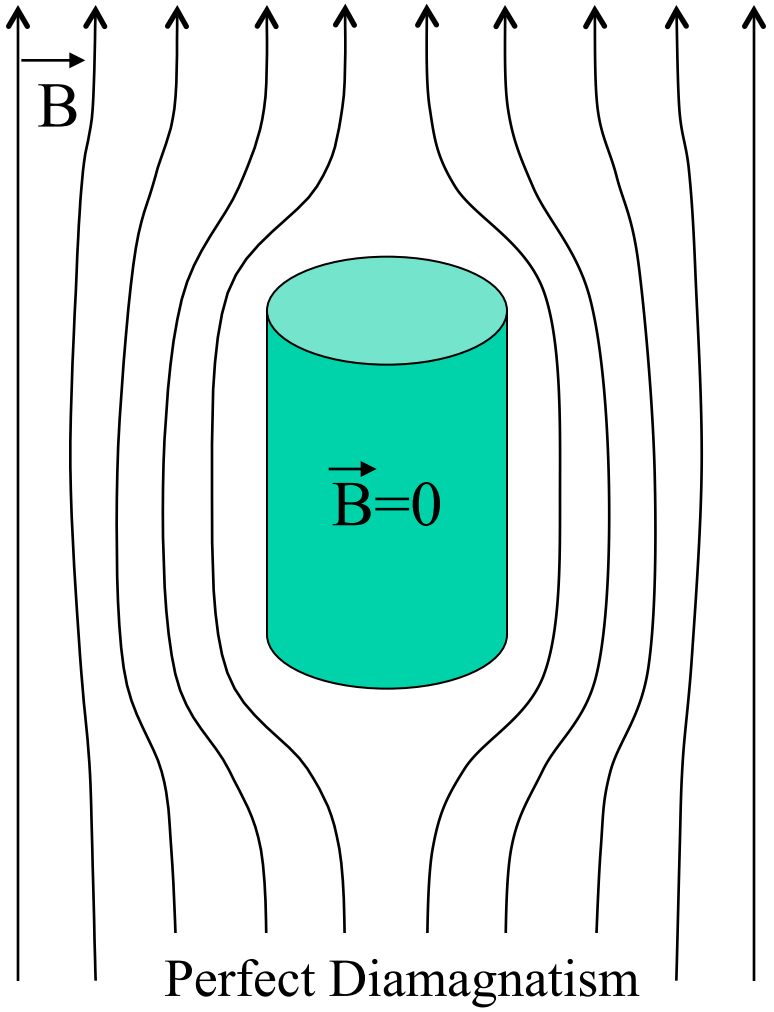
Superconductivity

- Zero resistance to dc current
- Expels magnetic fields
- A state of matter (like ice vs water) but of electrons
- Occurs below a critical temperature T_C, current density J_C, magnetic field B_C.

Superconductivity – discovered in 1911 by Kammerlingh Onnes



Onnes original plot of the resistance of Mercury versus temperature showing the first observed transition to the superconducting state.



Theory

Immediately recognized that superconductivity was connected to the new quantum theory,

"It has become more and more clear that a change in the whole theory of electrons is necessary. Theoretical work in this direction has already been begun by a number of research workers, particularly by Planck and Einstein."

- Nobel citation, Swedish Academy of Science, 1913.

Nobel Prizes

1913 – Kammerlingh Onnes (discovery in Hg)

1962 – Lev Landau (partially for SC)

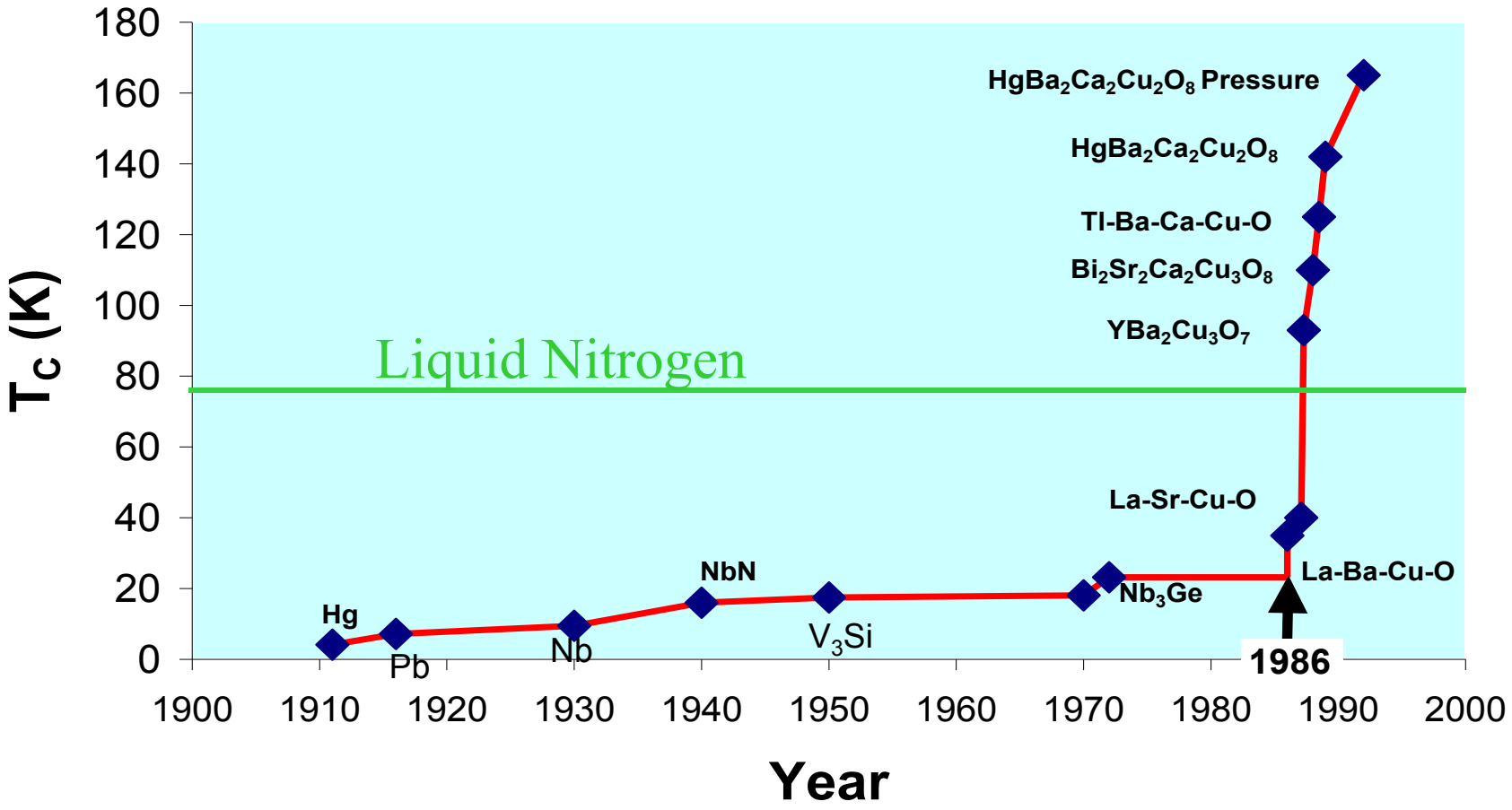
1972 – Bardeen, Cooper, Schrieffer (theory)

1973 – Esaki, Giaever, Josephson (tunneling)

1987 – Bednorz, Mueller (High Tc)

2003 – Abrikosov, Ginsburg, Leggett (vortices)

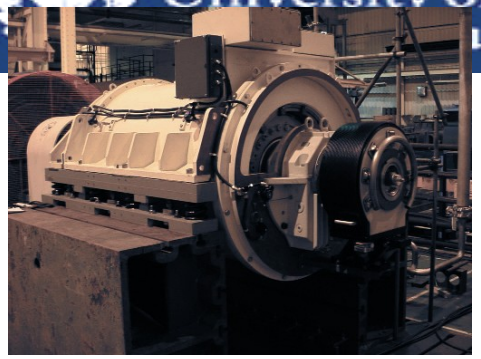
Record T_c versus Year Discovered



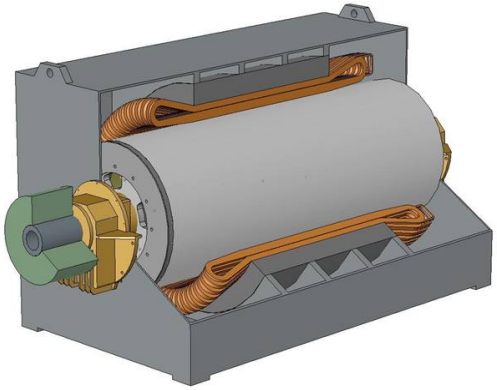
J. Bednorz and K.A. Muller, IBM Zurich


TIME
Wiring the Future
CONTRA ARMS
The Widening Web
THE
SUPERCONDUCTIVITY
REVOLUTION

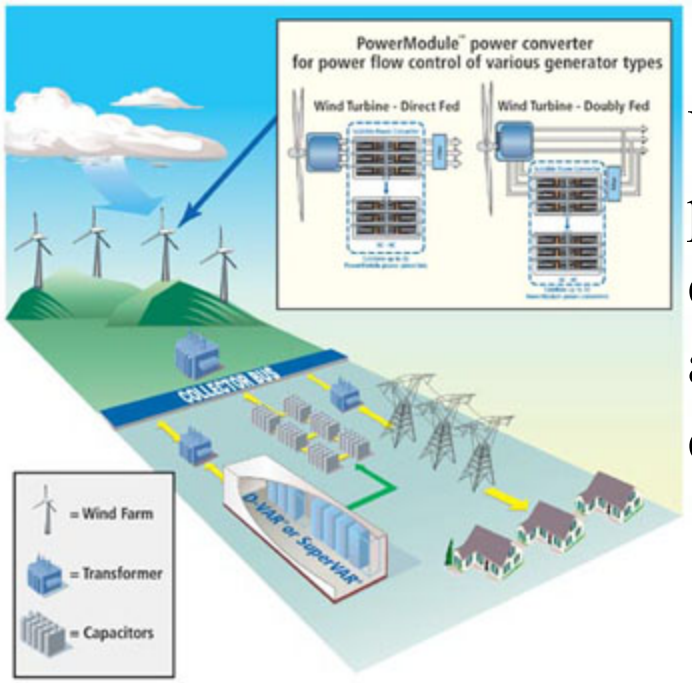
MRI of lower human spine / MRI Imager
(from, J.P. Hornak, The Basics of MRI)



Ship
Propulsion



SuperVAR
Power Grid
Regulation

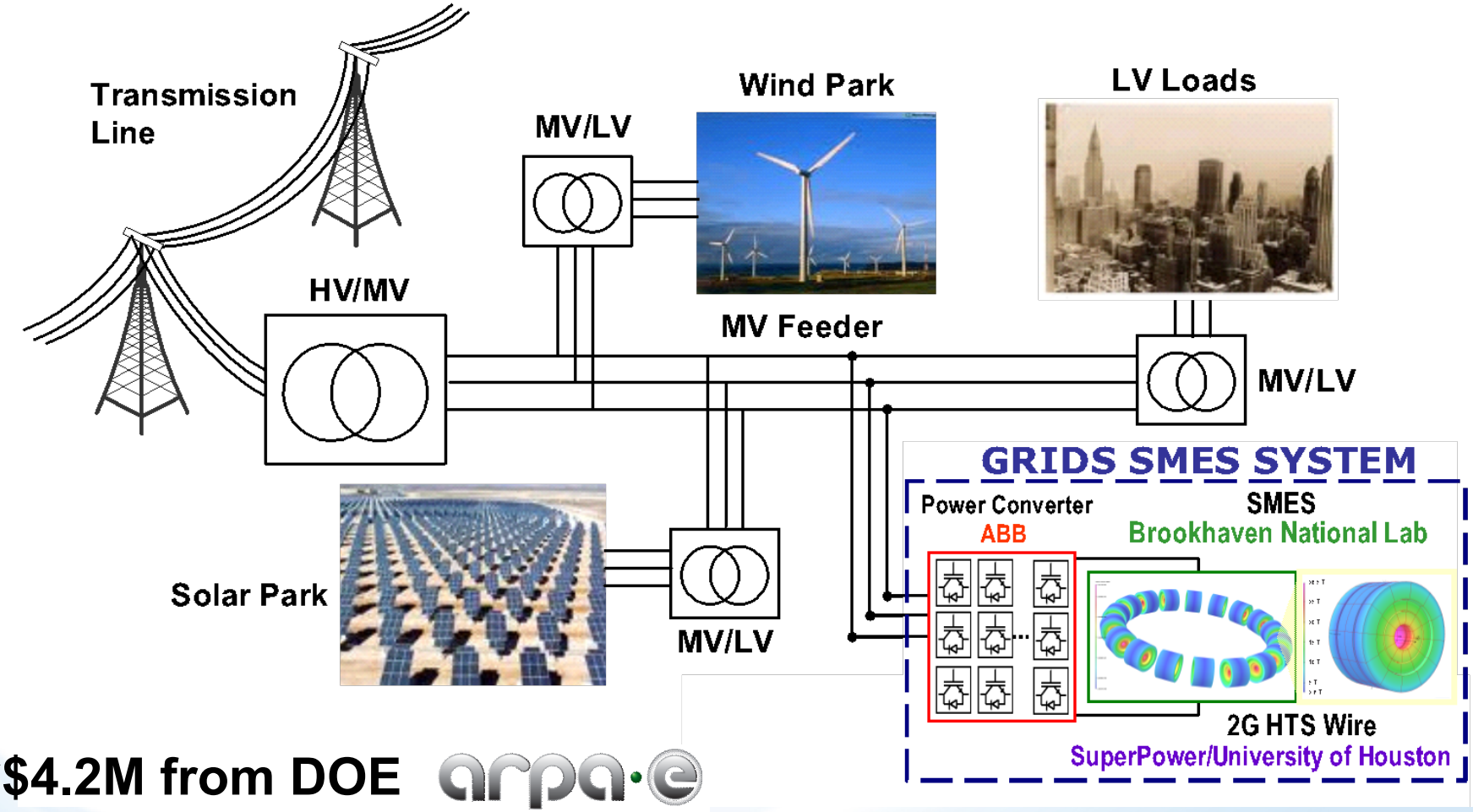


Wind Power
power
conversion
and grid
connection

Commercial power
distribution,
Holbrook, NY

American Superconductor
Westborough, MA

Superconducting Magnet Energy Storage (SMES) System with Direct Power Electronics Interface for GRIDS ($5.3M)*



*$4.2M from DOE

arpa·e

Team (co-PI): ABB Inc. (V.R. Ramanan), Brookhaven Lab (Q. Li), SuperPower, Inc. (D.Hazelton) /U of Houston

Oct. 2010

BROOKHAVEN NATIONAL LABORATORY


浮いた土佐ノ海
TOSANOUMI
(Sumo Wrestler)
Height of Tosanoumi 186cm
Weight of Tosanoumi 142kg
Weight of stick 03kg
Total weight 212kg


The japanese prototype maglev train

And … On The Web

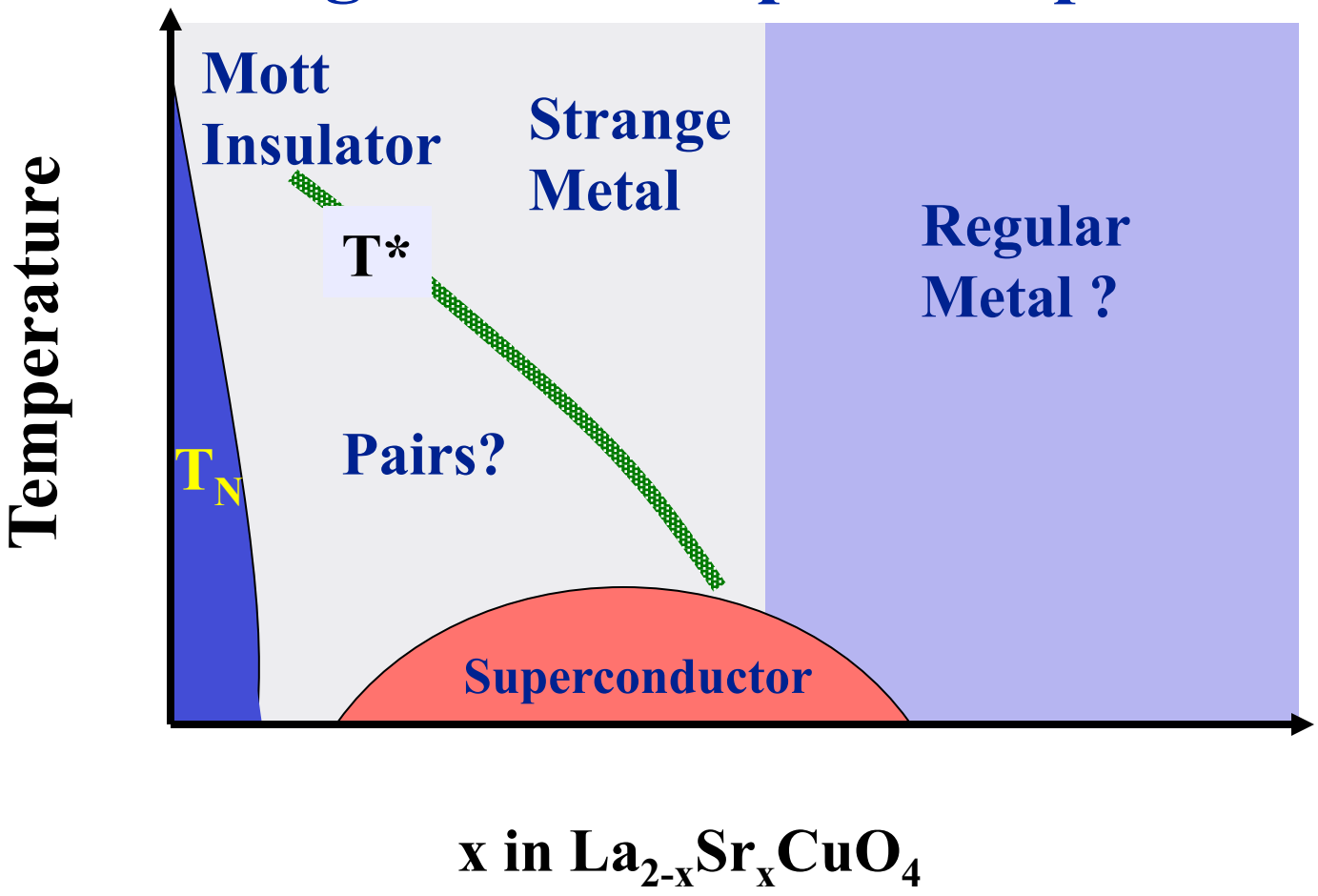
"What people don't know is that Billy Meyers, of … Pleiadian Switzerland fame, ostensibly gave the IBM folks in Zurich a sample of the metal from his beam ship, that was given to him by the E.T.'s"

Richard C. Hoagland
http://www.enterprisemission.com/gtran6.html

Cuprates 1986.

- All high T_C SC are XYZCuO.
- All are connected to insulating, magnetic parent compounds via charge doping.
- Why Cu?
- Why near magnetism?
- Why T_C so high? [Higher?]

Phase Diagram for Cuprate Superconductors



Iron Pnictides - 2008.

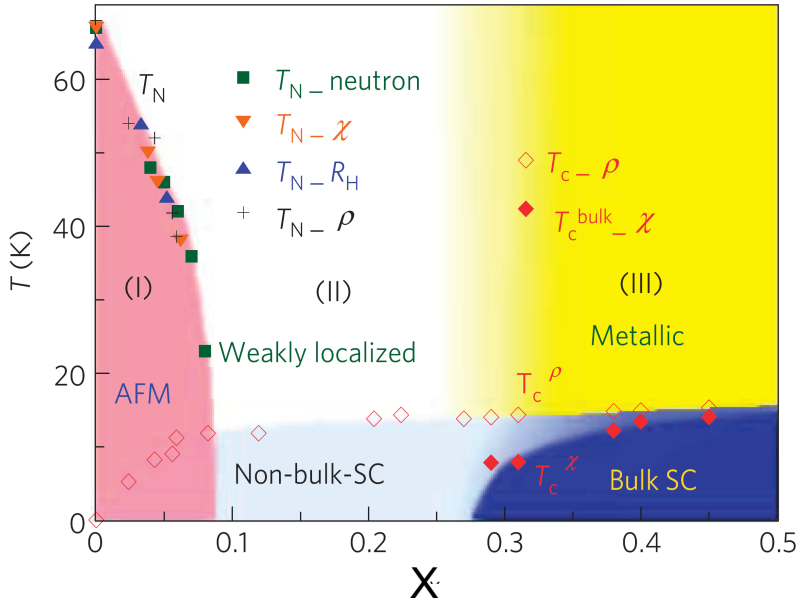
- Second group of high T_C superconductors.
- All are connected to conducting, magnetic parent compounds via some kind of doping.
- Why Cu and Fe?
- Why near magnetism?
- What is doping?

FeTe parent (magnetic, not SC)

substitute Se to make SC

Up to FeSe

$Fe_{1.02}Te_{1-x}Se_x$



isovalent doping

Apparently strain not charge.

Nature Materials **9** , 718–720 (2010)

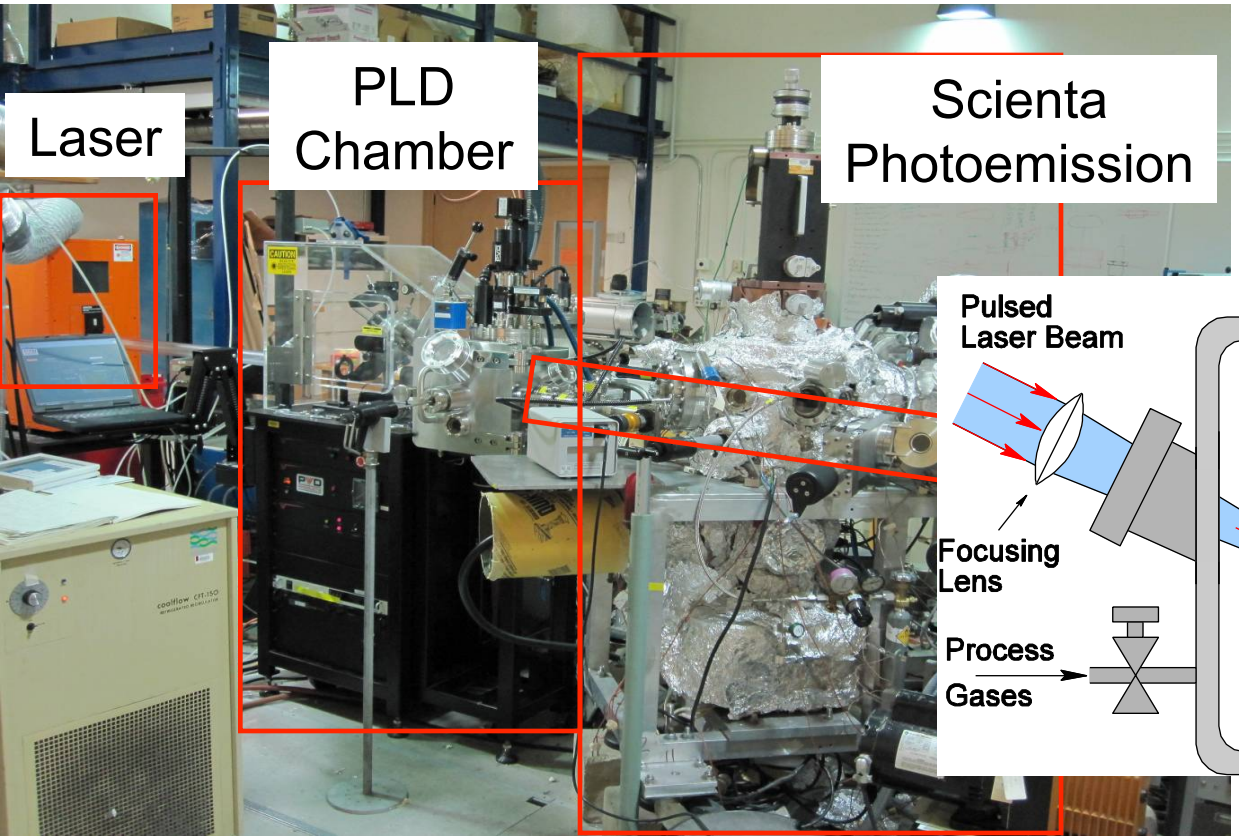
Our Group – What We Do

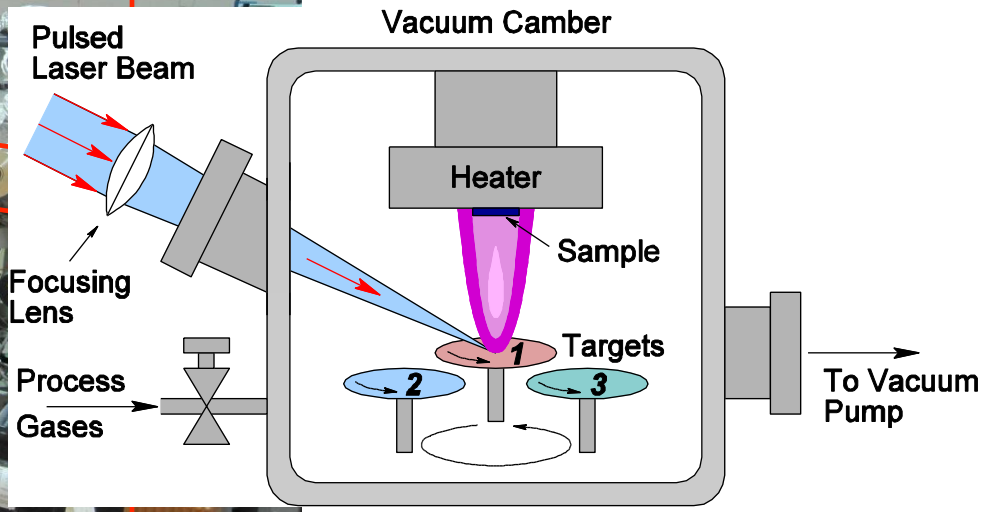
Synthesis – Grow Films

Pulsed Laser Deposition (PLD), upgrade almost done.

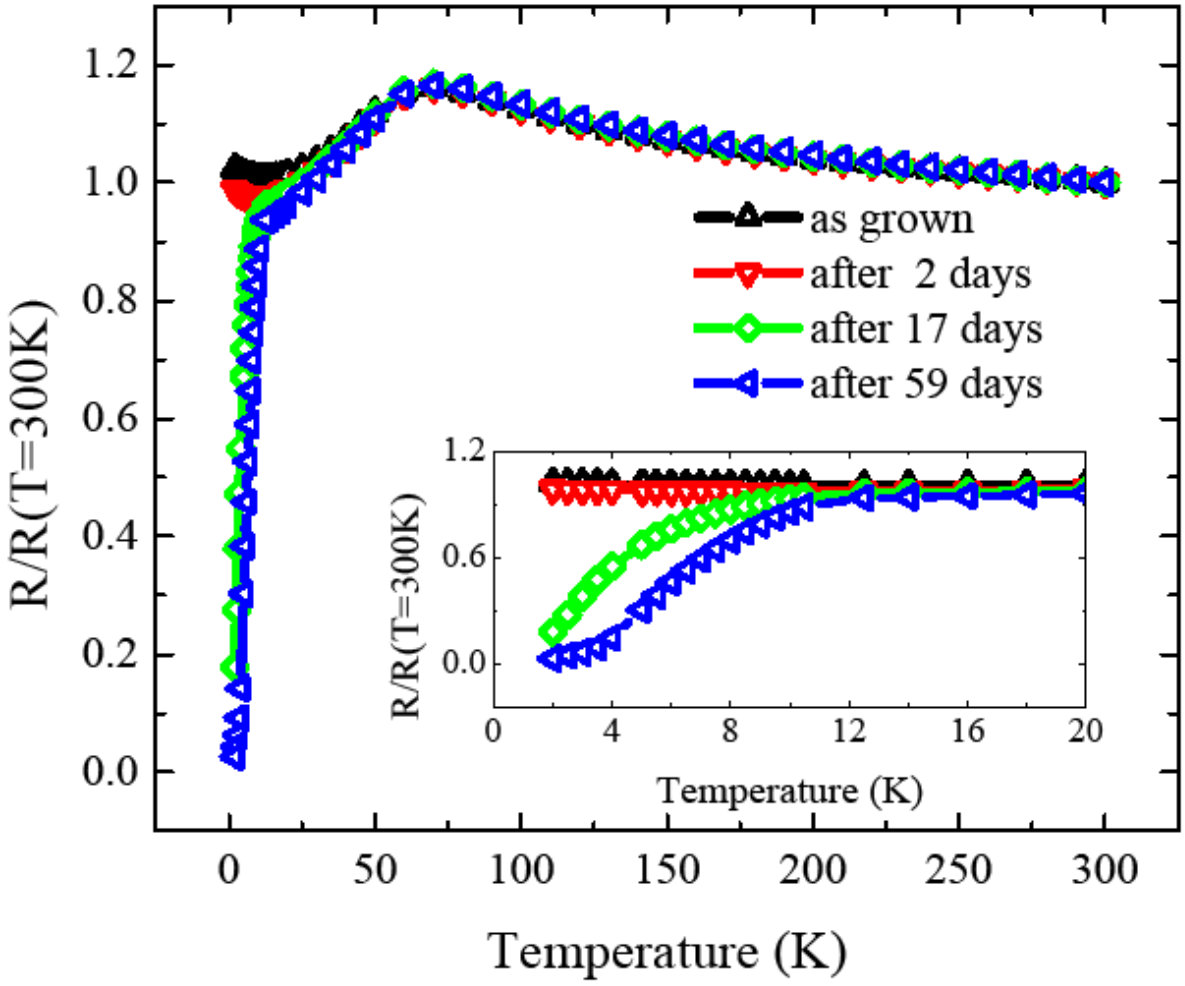
Flexible system for growing new systems quickly.

– oxygen control: annealing, ozone, electrochemistry.





Air exposure



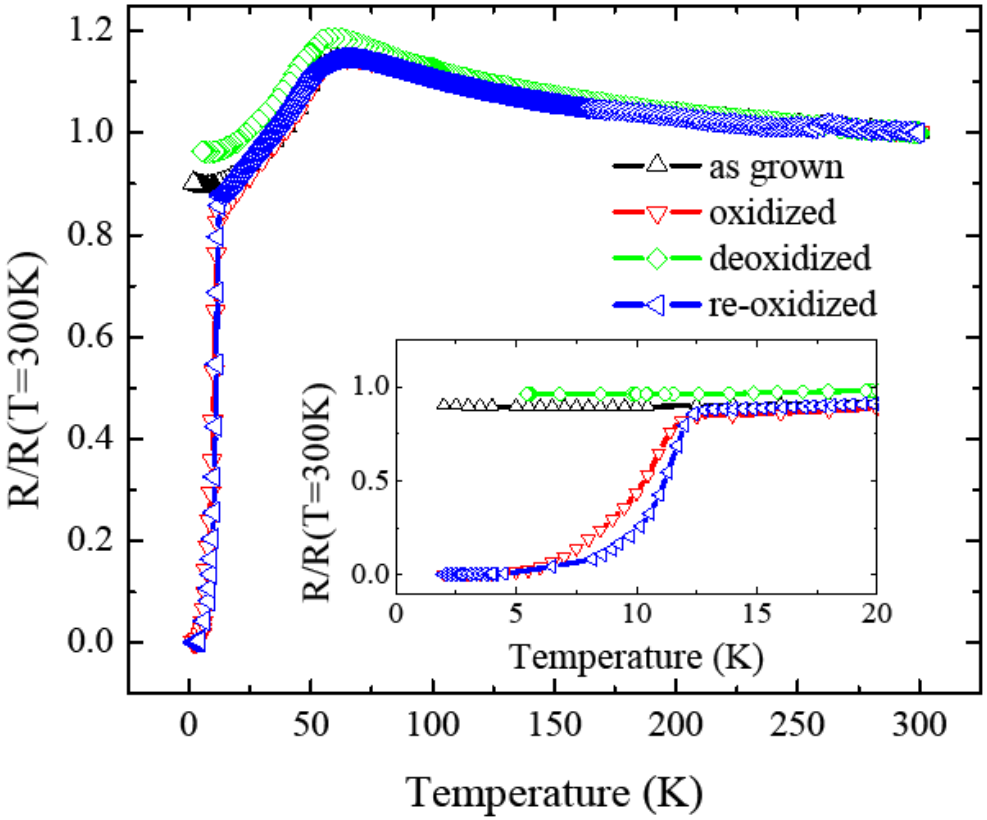
Two other reports of SC in FeTe films:

1. Y. Han et al., Phys. Rev. Lett. **104**, 017003 (2010)
2. W. Si et al., Phys. Rev. B **81**, 092506 (2010)

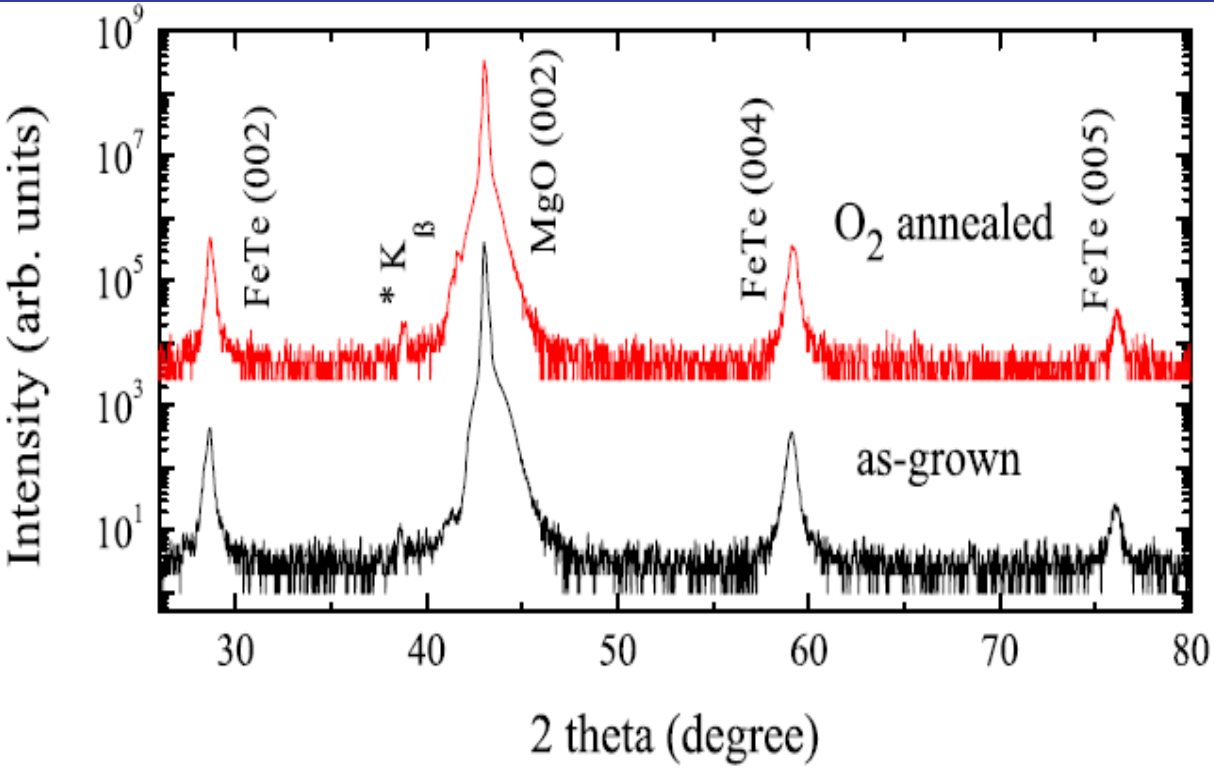
Oxygen Annealing Reversibility

Annealing in O_2, N_2, CO_2, H_2O, vacuum. Only O_2 → SC

Process is reversible.



Structure by XRD



Films are clean, tetragonal, (001) orientation.

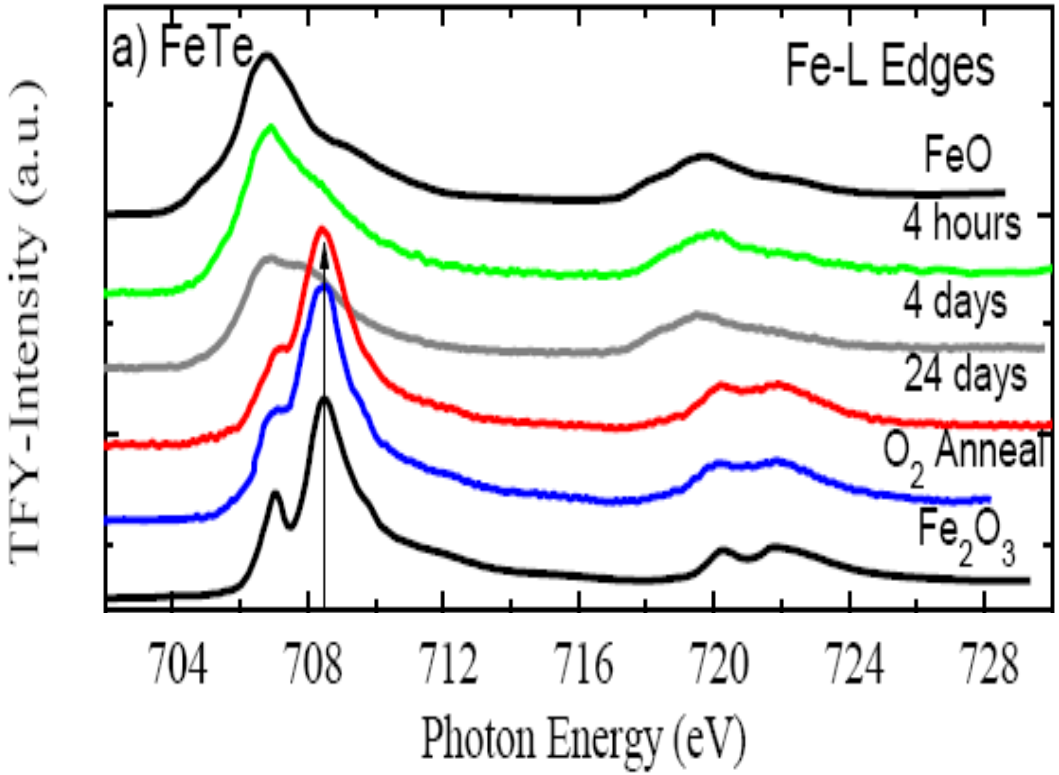
Oxygen annealing adds no new phases.

Small lattice constant change.

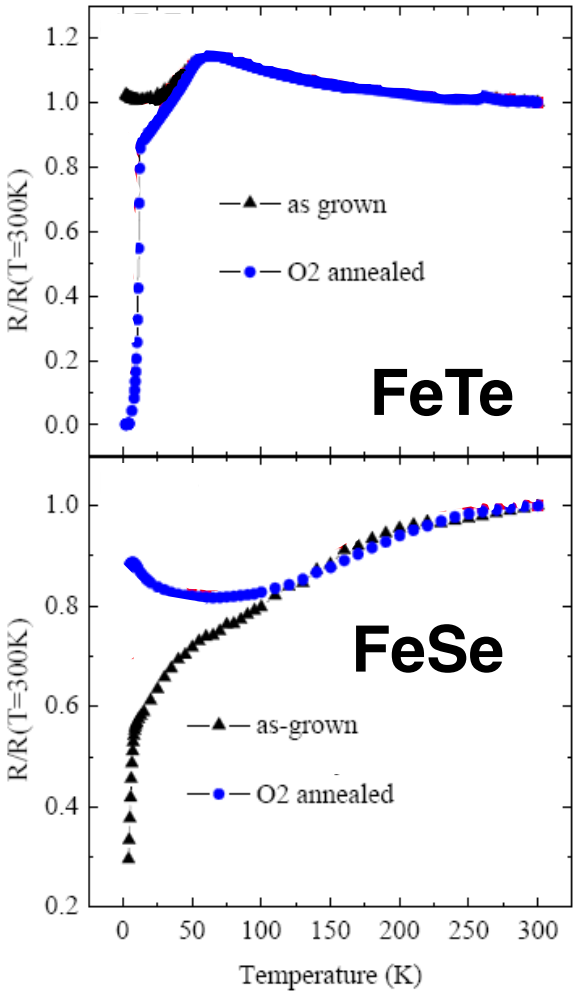
As grown, $a=b=3.83582$ Å and $c=6.27341$ Å.
Oxygenated $a=b=3.77821$ Å, and $c=6.28351$ Å.

Electronic State – Fe valence

XAS Fe L2, L3 edge.
TFY detection (TEY very similar)
SC films look like Fe^{3+}



What about FeSe?



FeTe – as grown non-SC

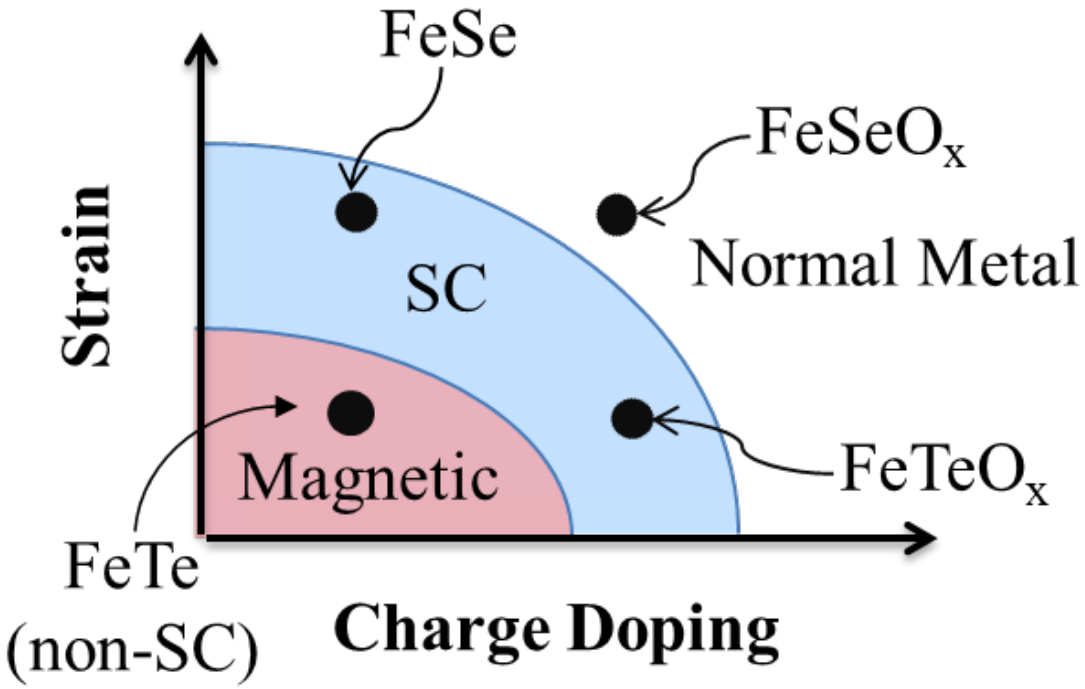
– oxidized SC

FeSe – as grown SC

– oxidized non-SC

Both – little change T > 100 K

A Possible T=0 Phase Diagram



Issues:

What exactly is strain?

Charge doping large here – vs $LaO_{1-x}F_xFeAs$

$FeSeO_x$ not SC, but normal metal?