

The Discovery of Superconducting Tunneling

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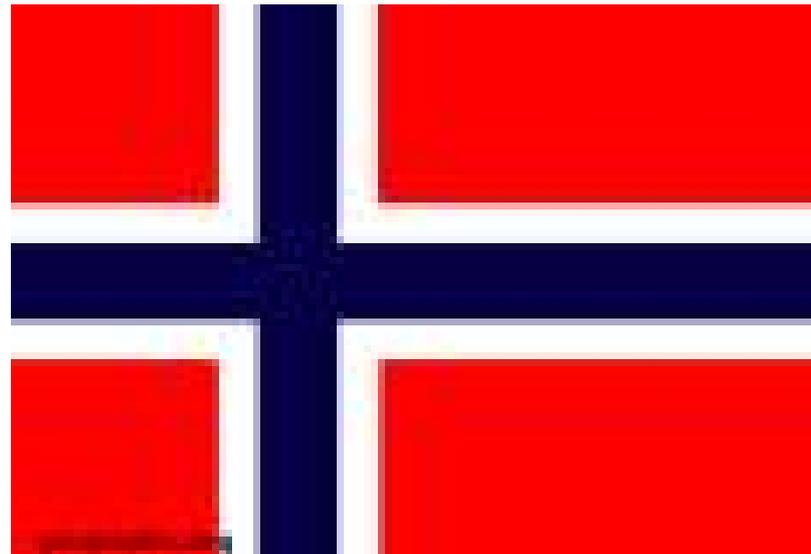
Troy NY 12180-3590

How it all began.....



Kingdom of Norway

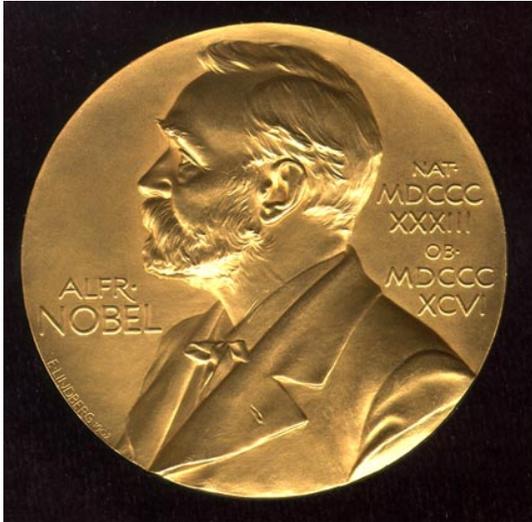
~ 4.5 Million people



I am a mechanical engineer from Norwegian
Institute of Technology (1952)



How a mechanical engineer ended up with the Nobel Prize in physics



**LUCK IS A
NECESSARY
INGREDIENT**

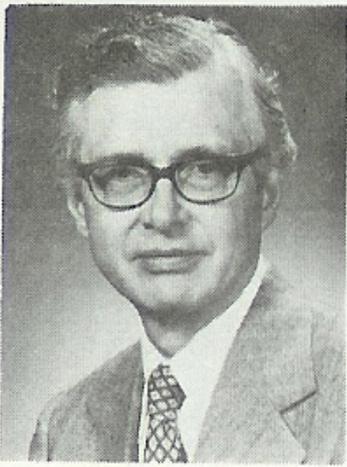
In Norway 1.0 is the best grade, 4.0 is barely passing, and 6.0 is failing, in USA on the other hand, 4.0 is the best grade you can get

I was not a good student in Norway and received 4.0 in both Physics and Mathematics.

GE Global Research Laboratory Niskayuna NY



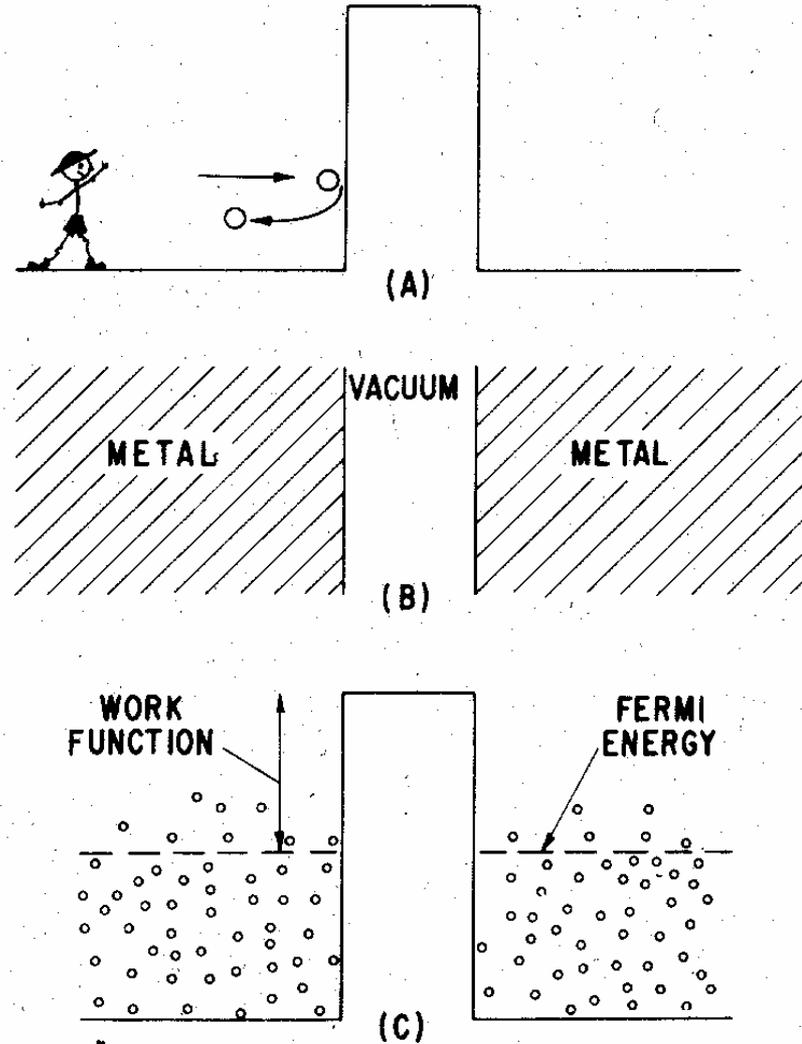
GE recruiter: I see you have 4.0 in both physics and math, you must have been a good student!!



Fisher, J.C.

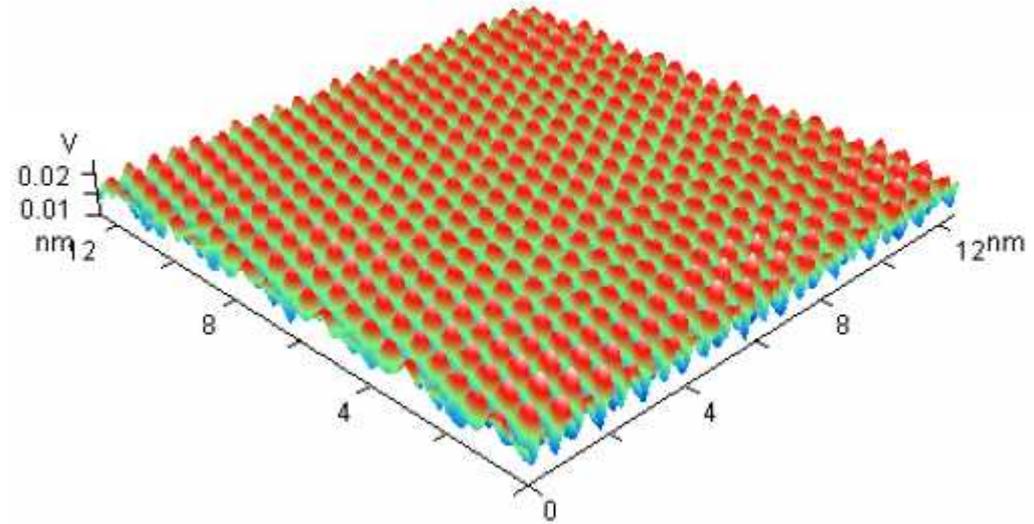
Principle of Tunneling

John C. Fisher, my mentor at GE, told me about tunneling, but since I was unfamiliar with quantum mechanics, I did not believe a word of it. .



How do you space two metals less than 5 nm apart?

I tried many different approaches, such as Langmuir films, mercury electrodes etc. but the current-voltage characteristics were non reproducible



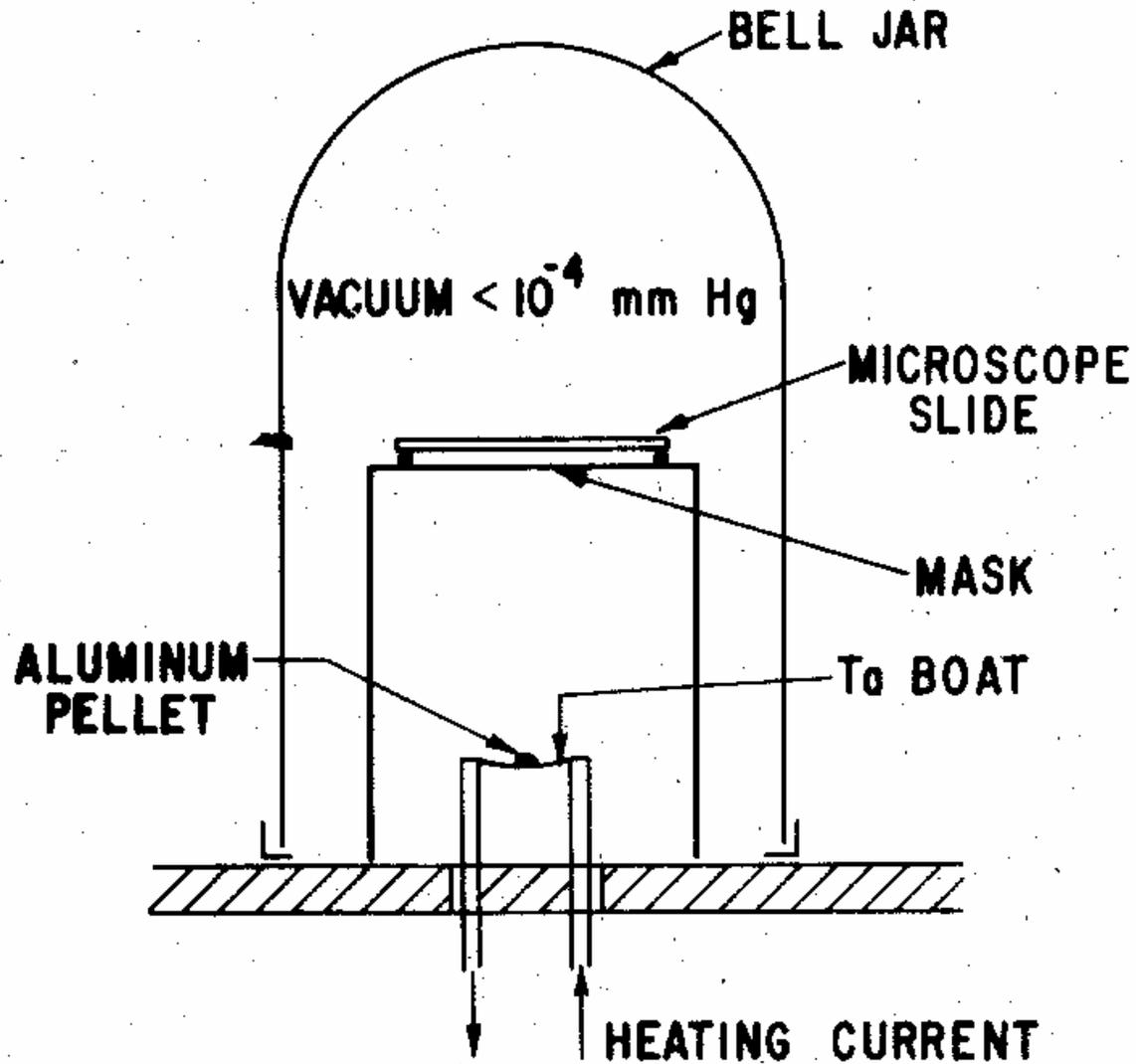
Dr. Fisher referred to my attempts as miracles..

...because different from science, miracles only happens once!

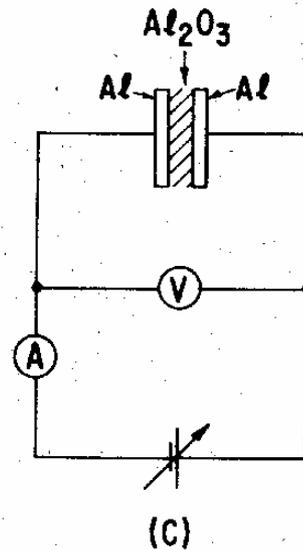
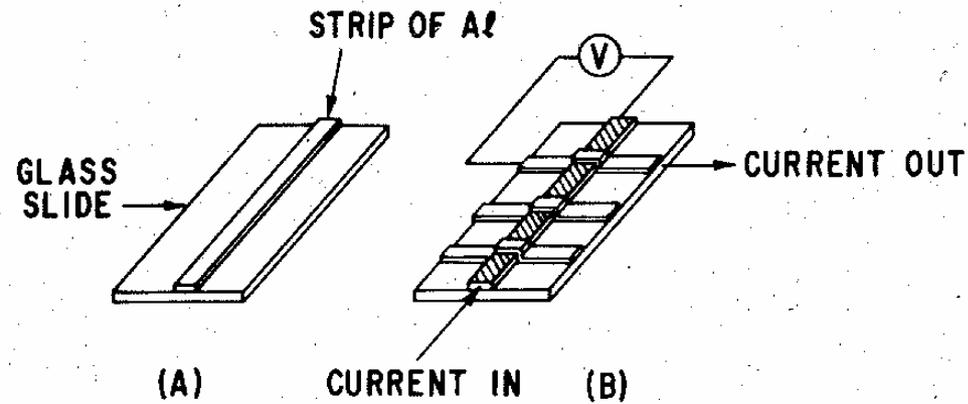
Inovating research often requires that you build your own apparatus



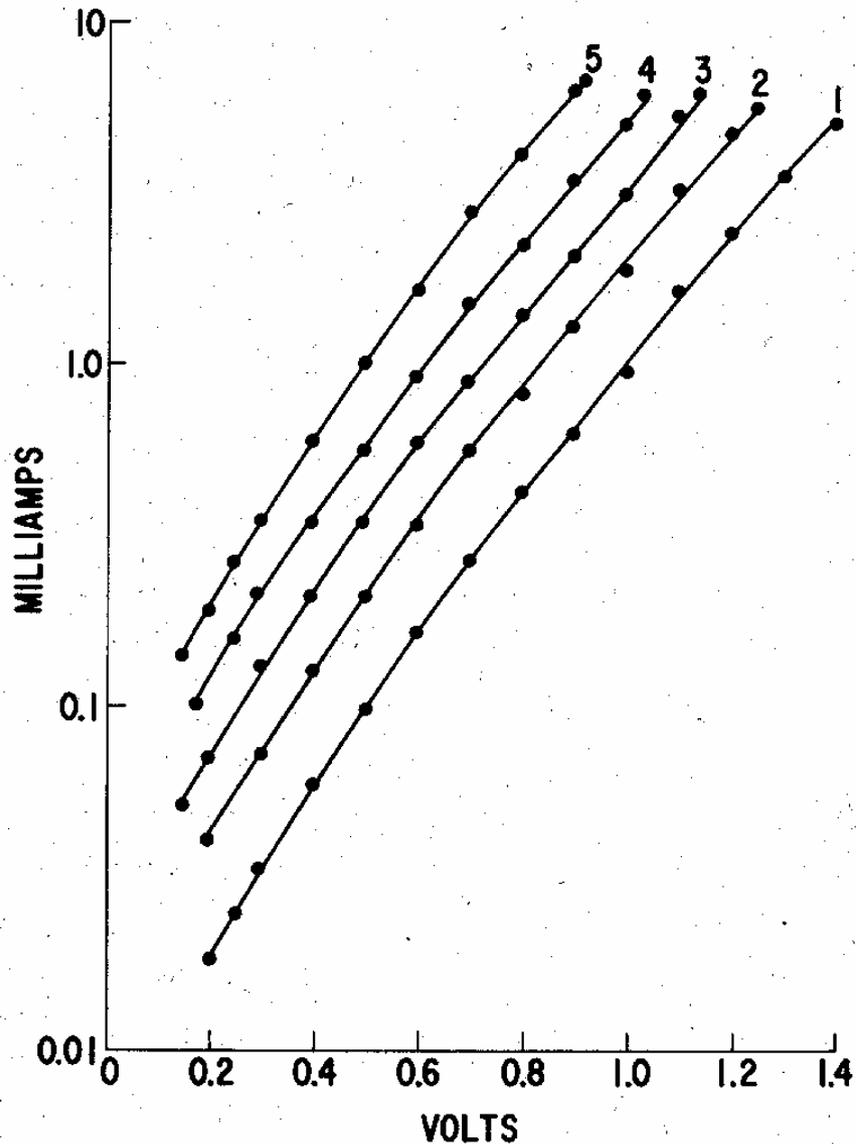
A Vacuum Evaporator



The making of a tunnel junction



Al-Al₂O₃-Al Tunnel Junction



**Current was
proportional with area**

**Current was (almost)
independent of
temperature**

My lab at General Electric in 1973



I gave a seminar at GE, the audience clapped politely.



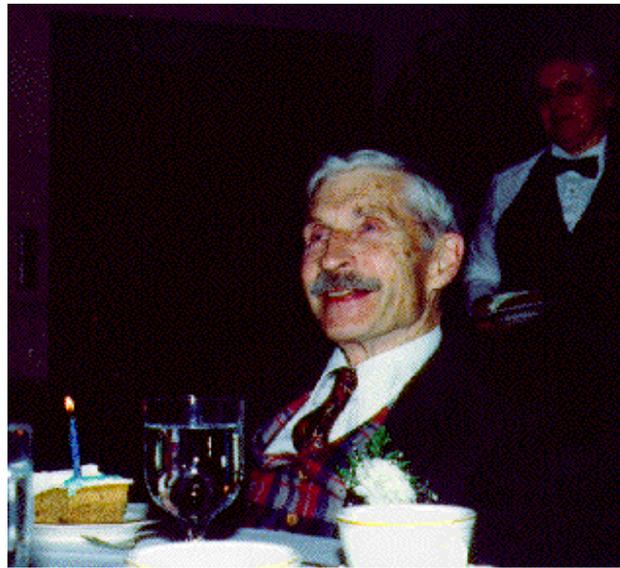
Several questions came up: How do you know the results are not due to semi-conducting, ionic-conducting, small metal bridges etc.

This challenged me!

Rensselaer Polytechnic Institute (**RPI**)



Studied quantum mechanics and physics

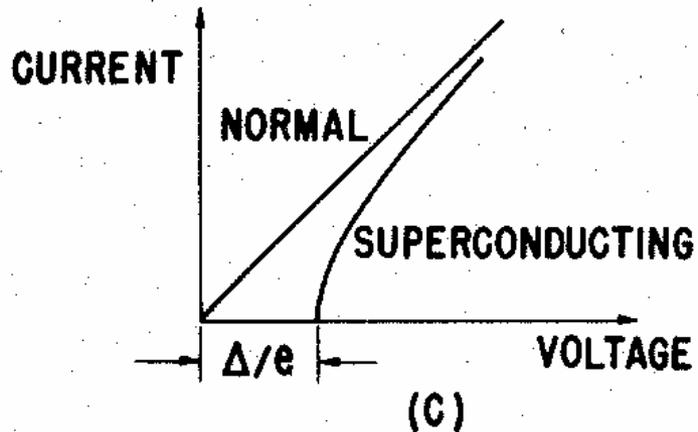
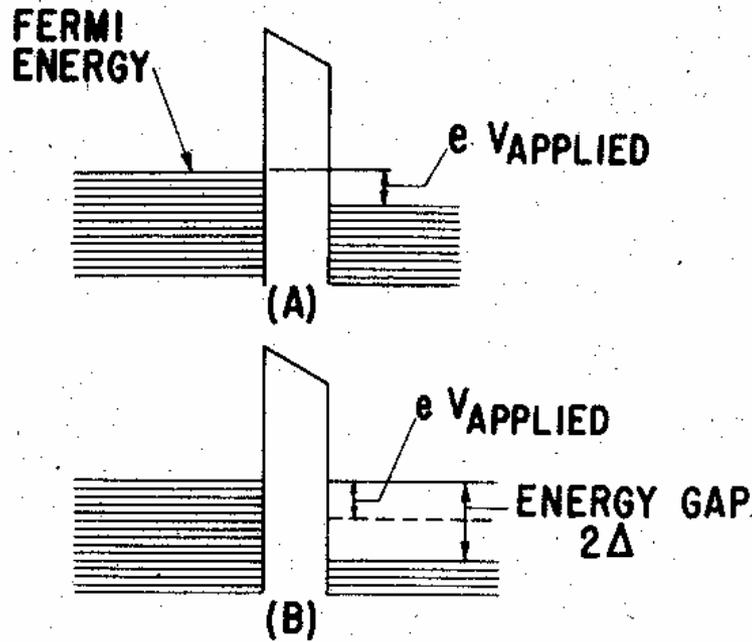


Professor Huntington lectured about superconductivity, the BCS theory and the energy gap

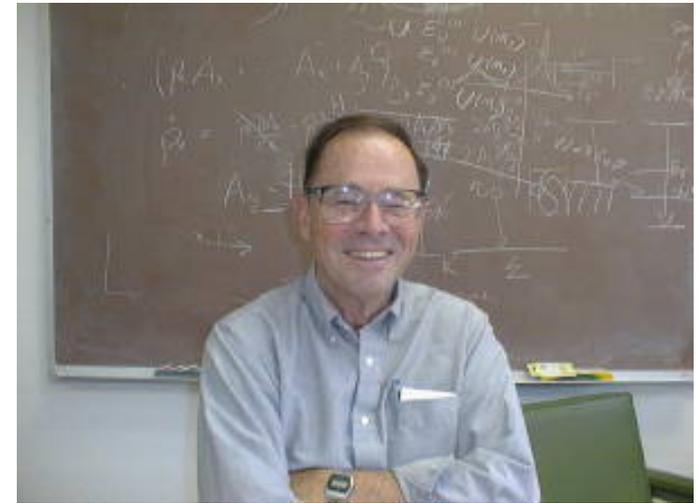
In his class I got the **IDEA** that I could measure the energy gap using tunneling.

Always go to class, you never know what you might miss and the payoff is sometimes **BIG**

The Big Idea

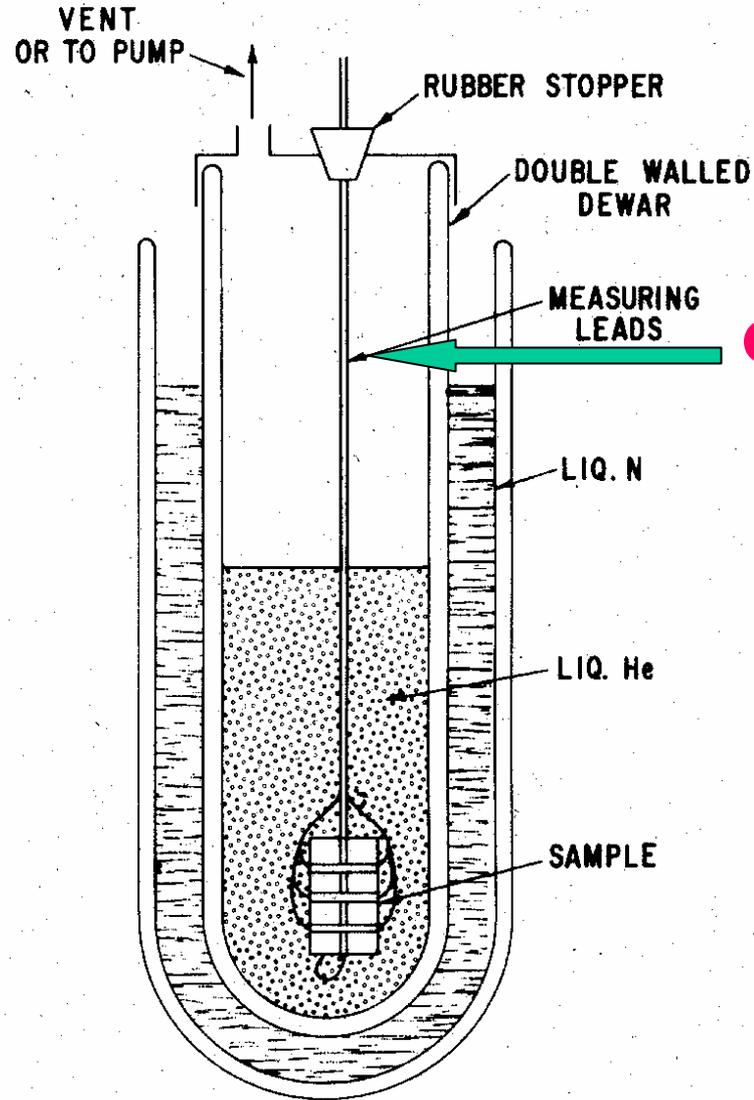


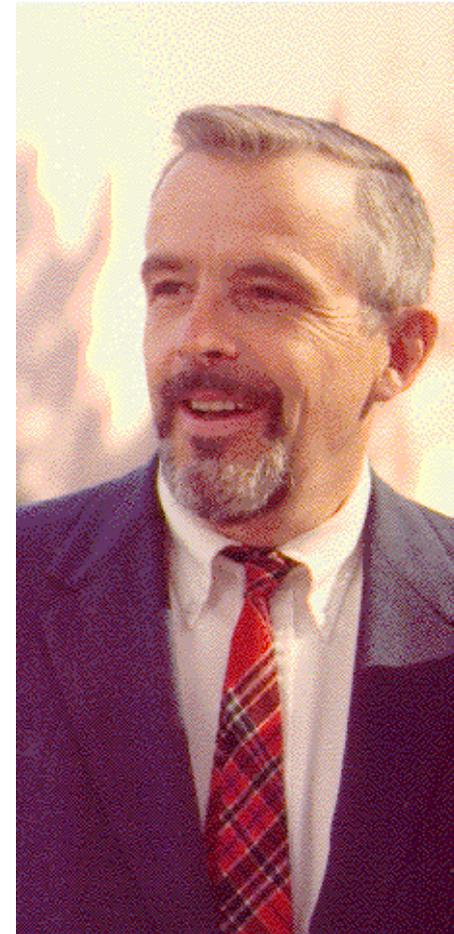
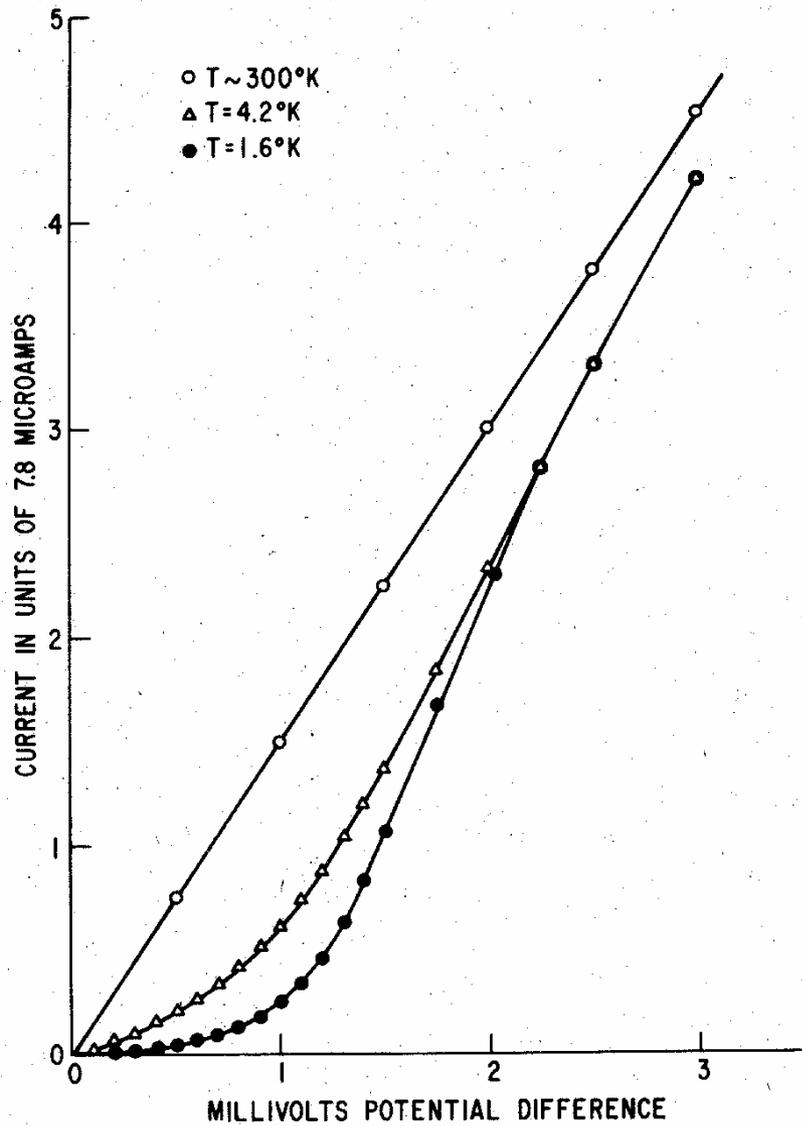
But how big was the gap?



Walter A. Harrison

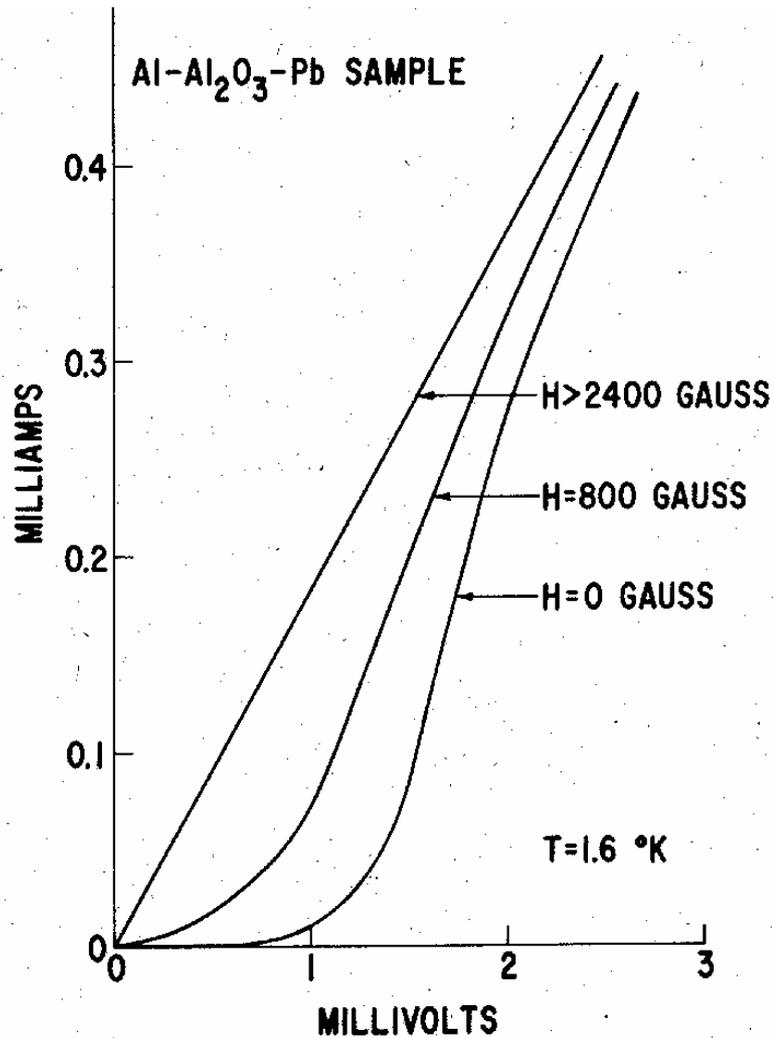
The First Superconducting Tunneling Experiment





Charles P. Bean

The Crucial Experiment

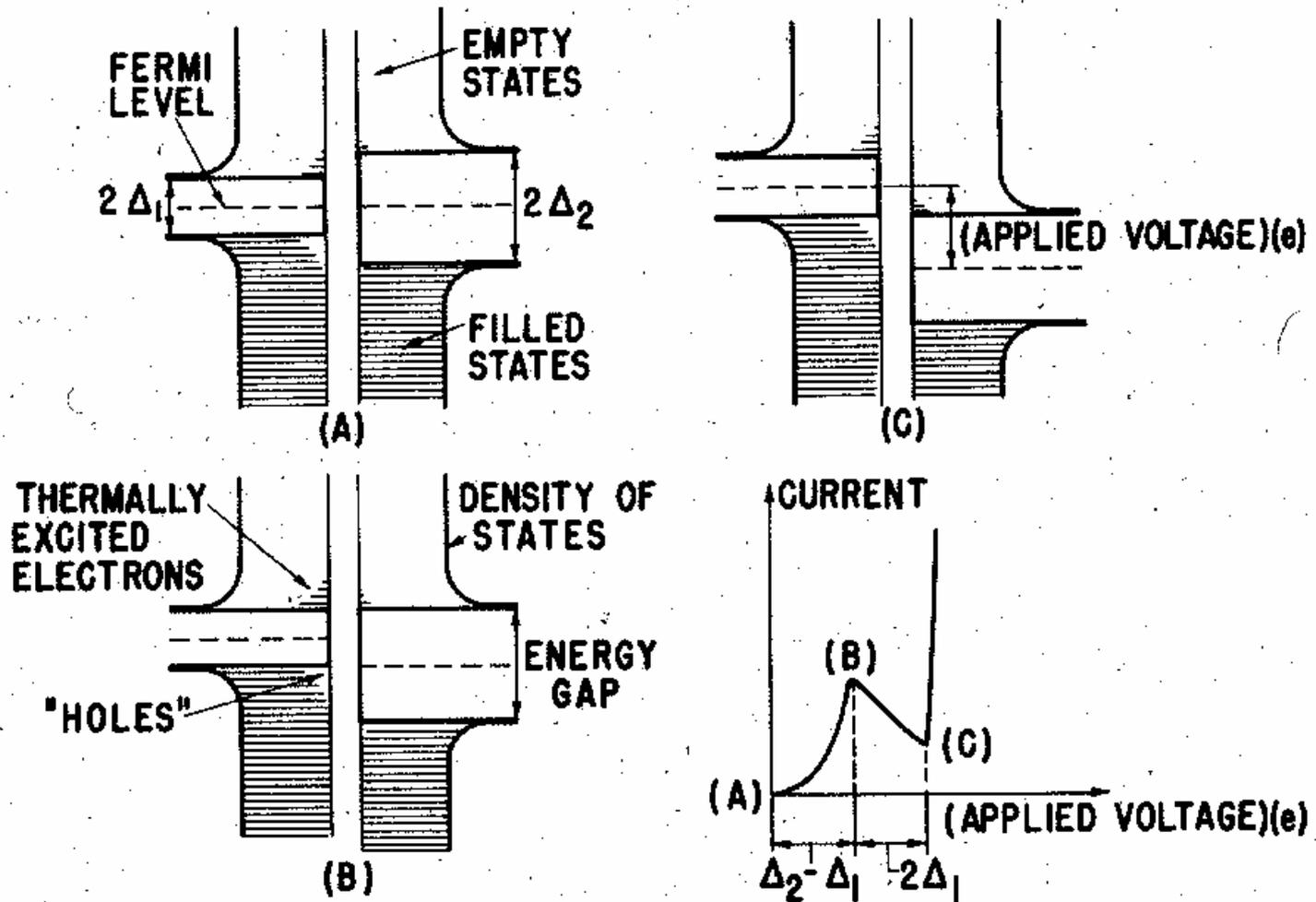


It is **VERY** important to try to prove yourself wrong; if the experiment is important other scientists certainly would do so.

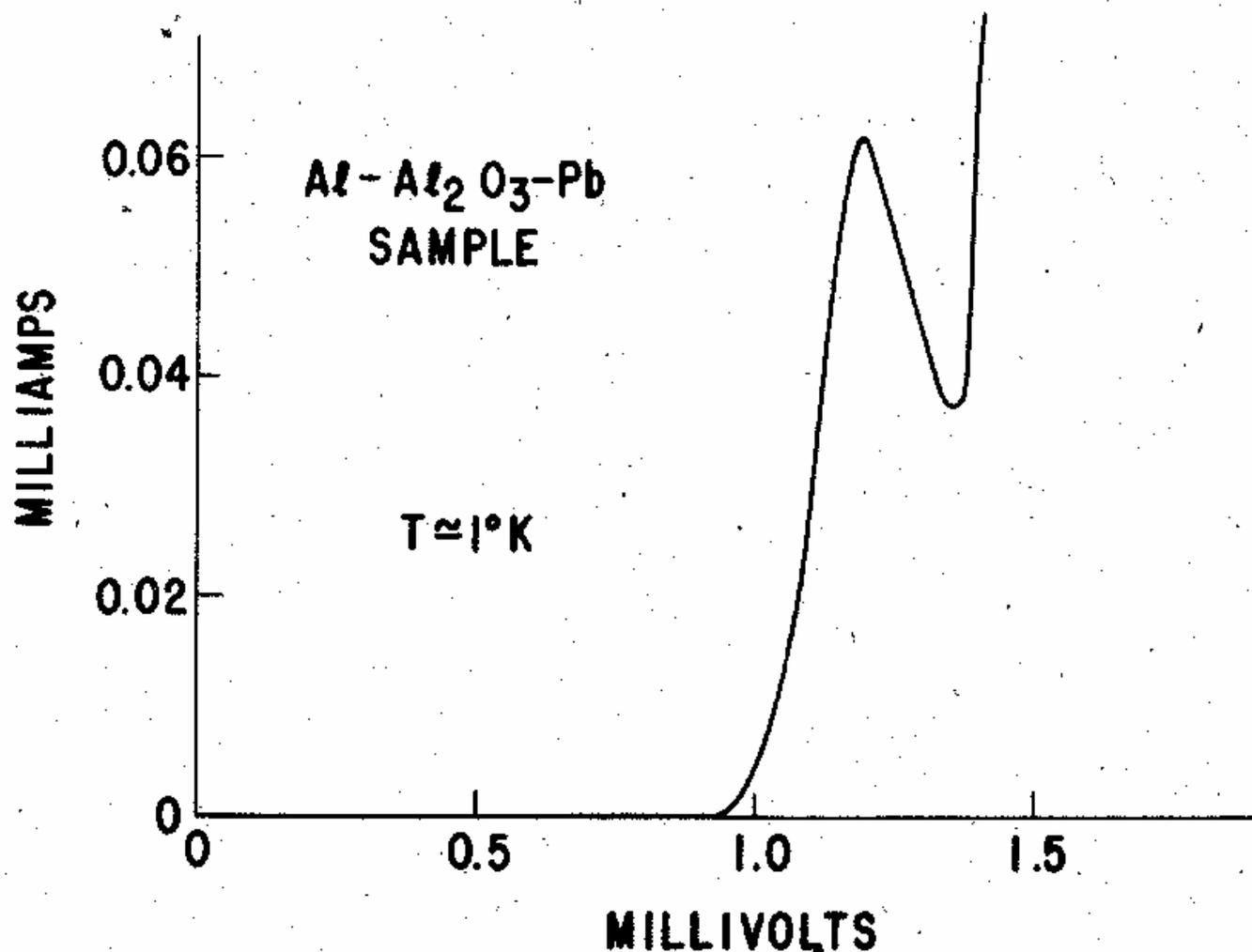


Explaining my result to 3 real physicists and helpful friends: Harrison, Bean and Fisher

But what about 2 superconductors?



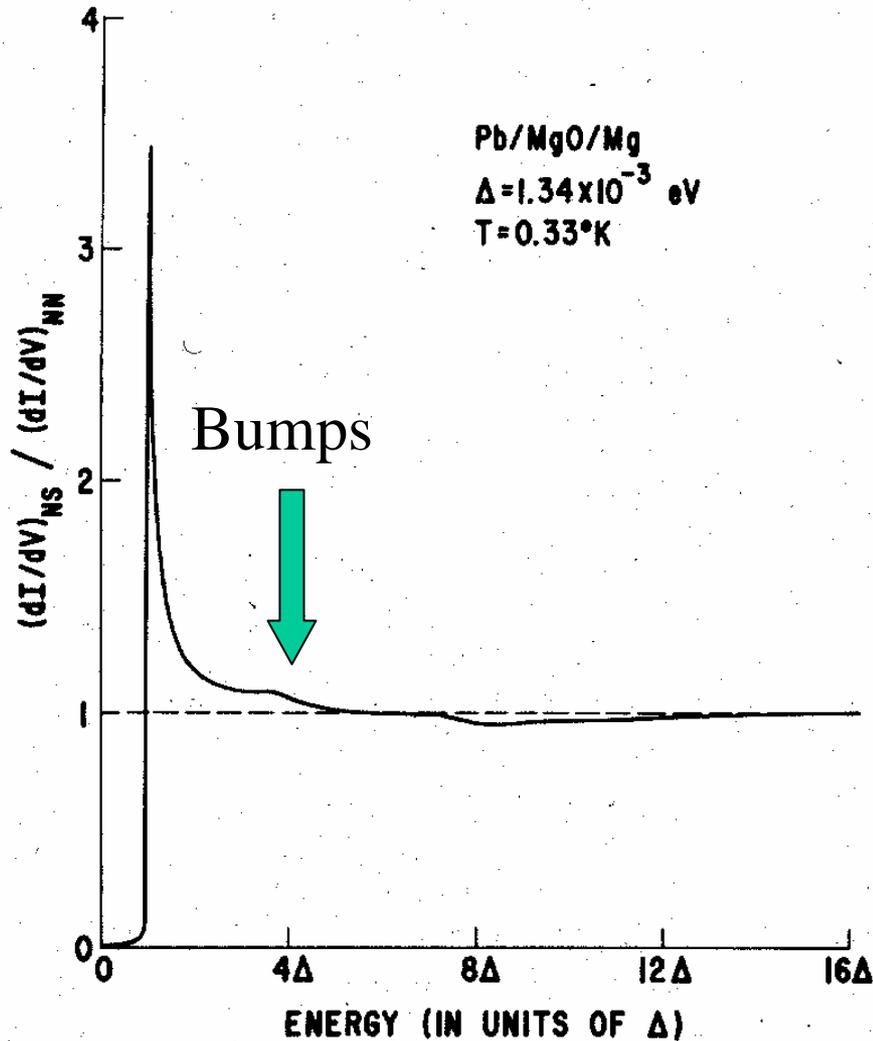
Just as predicted!





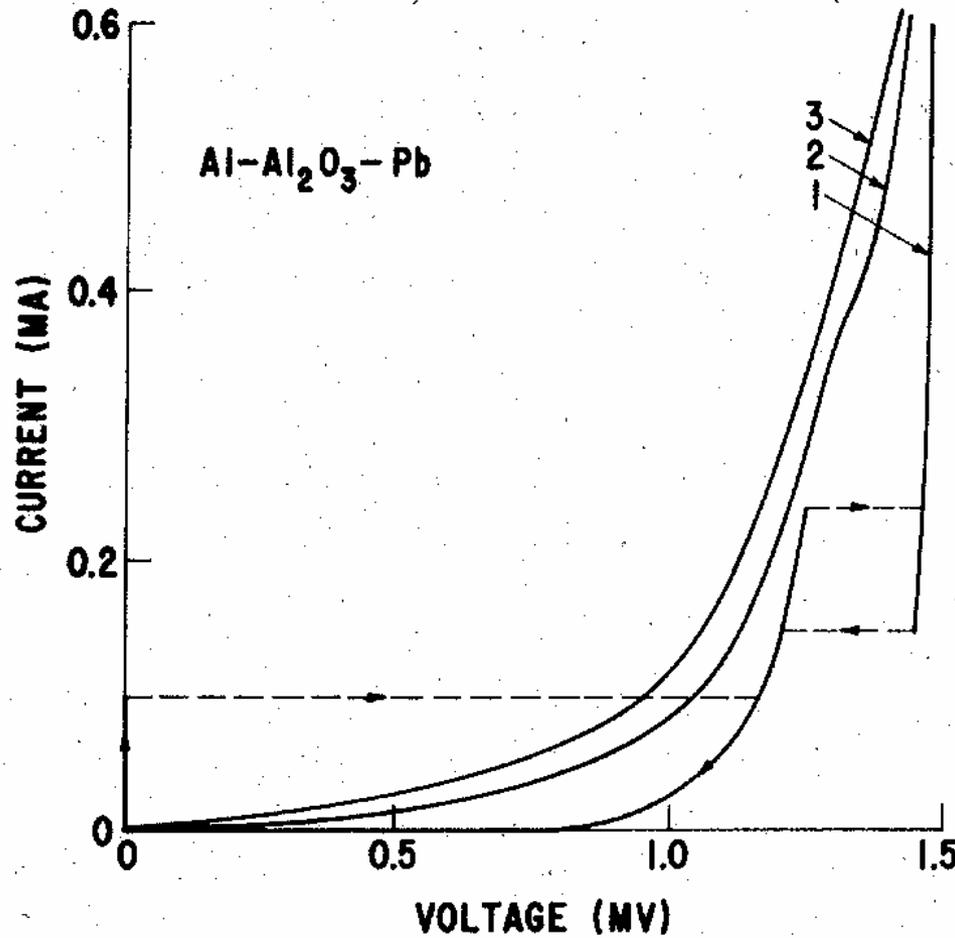
Schmitt, Giaever, Bardeen and Bean

An experimentalist's dream is to disprove a famous theory



Simple theory predict exponential approach to 1.0

What I missed.....



1 No magnetic field

2. & 3. Moderate and high magnetic field

Now known as the Josephson Effect



What **IS** the Josephson Effect?

DC effect:

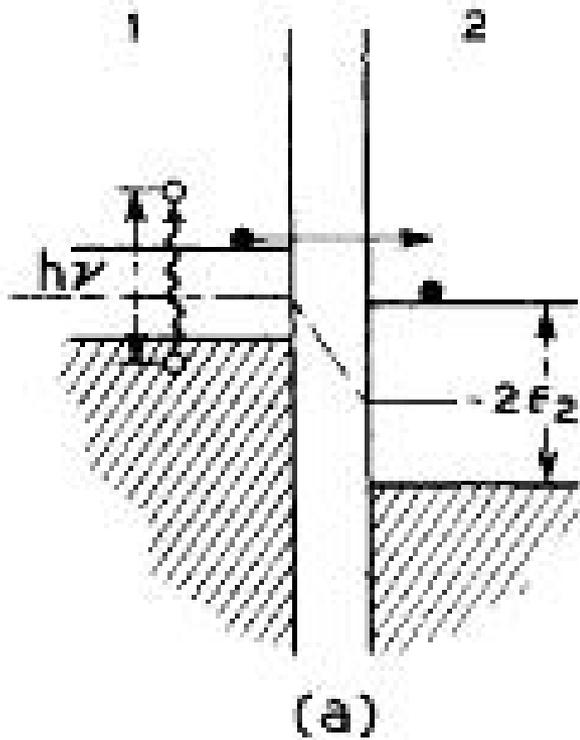
Supercurrent can flow through insulating layers with no resistance

AC effect:

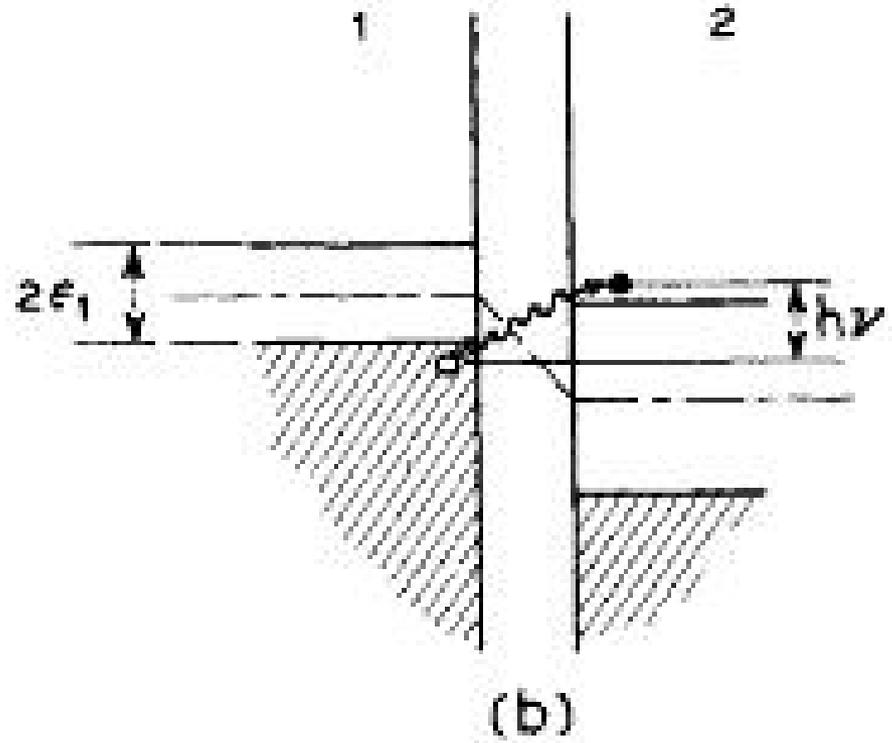
With an applied voltage, V , across the insulating layer, the junction would radiate at a frequency of $2eV/h$

Photon Assisted Tunneling

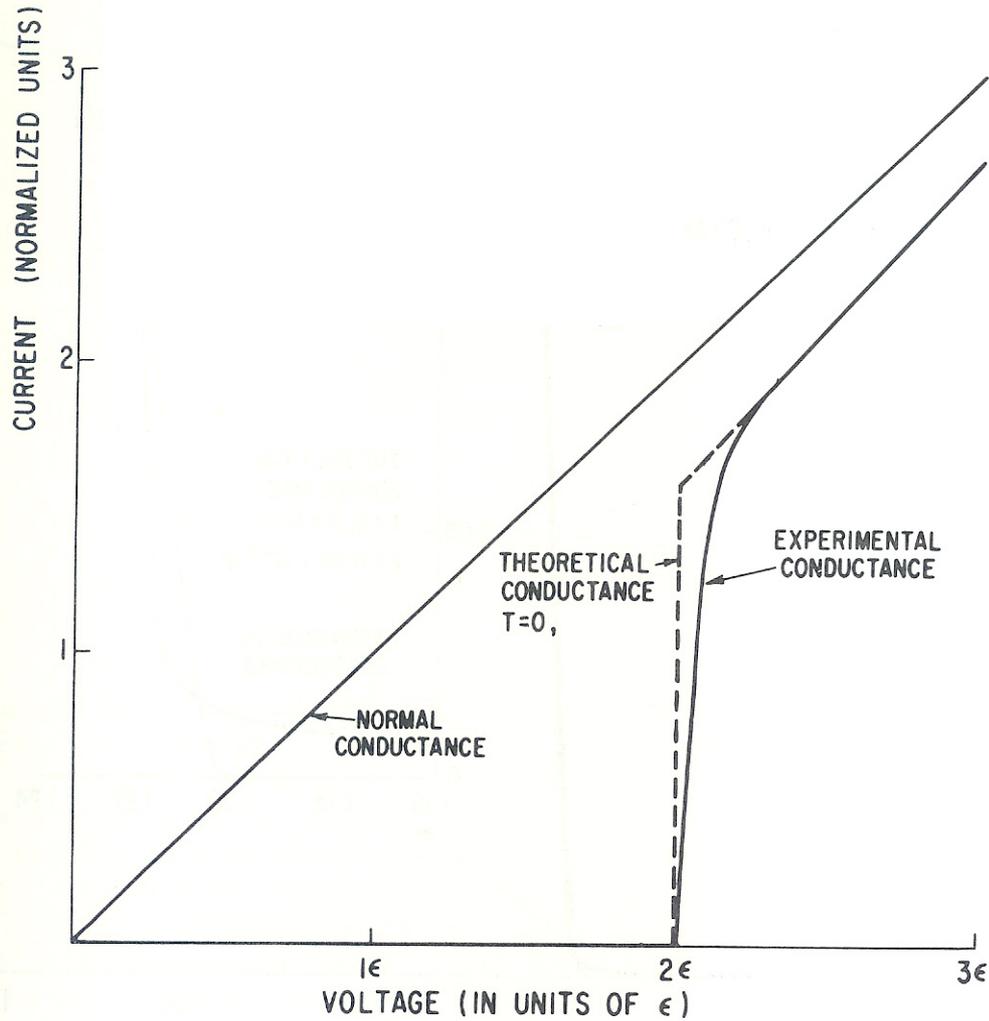
Photon changes the energy of the electron before tunneling



Photon changes the energy of the electron during tunneling

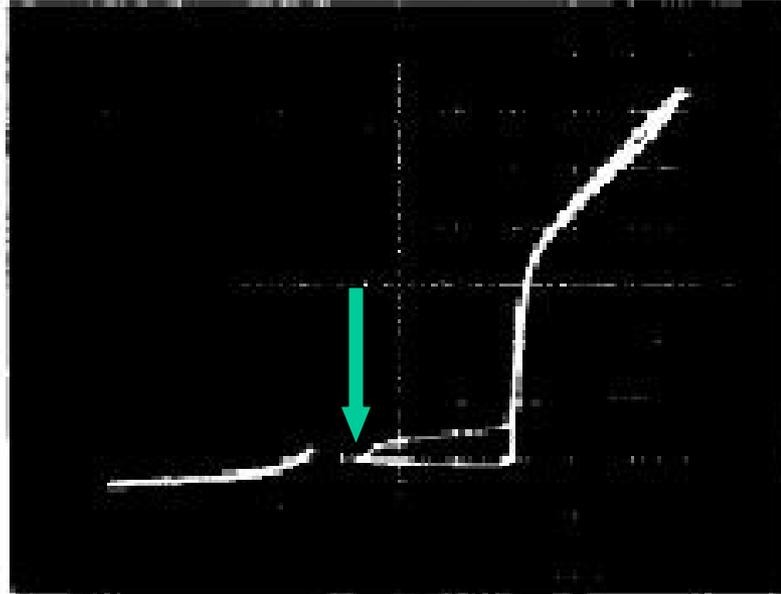


Sn/SnO/Sn Junction 0.30 °K



Junction as a detector

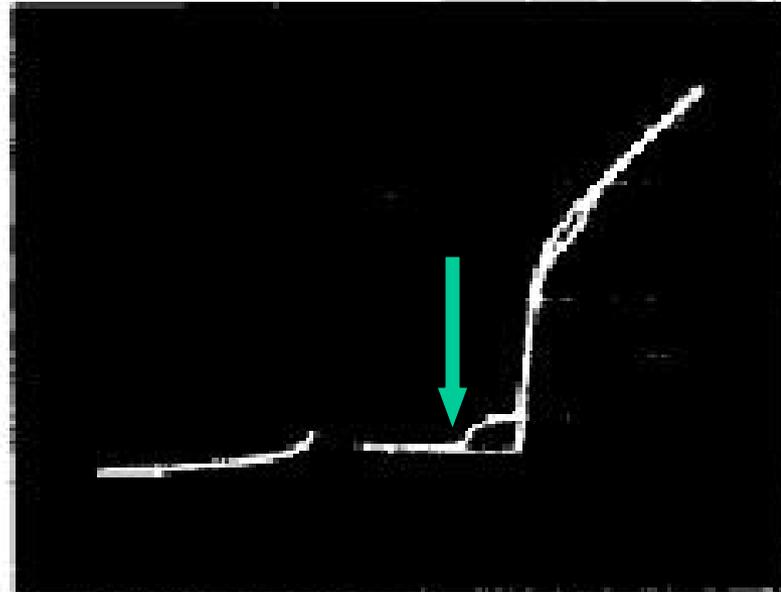
High
frequency

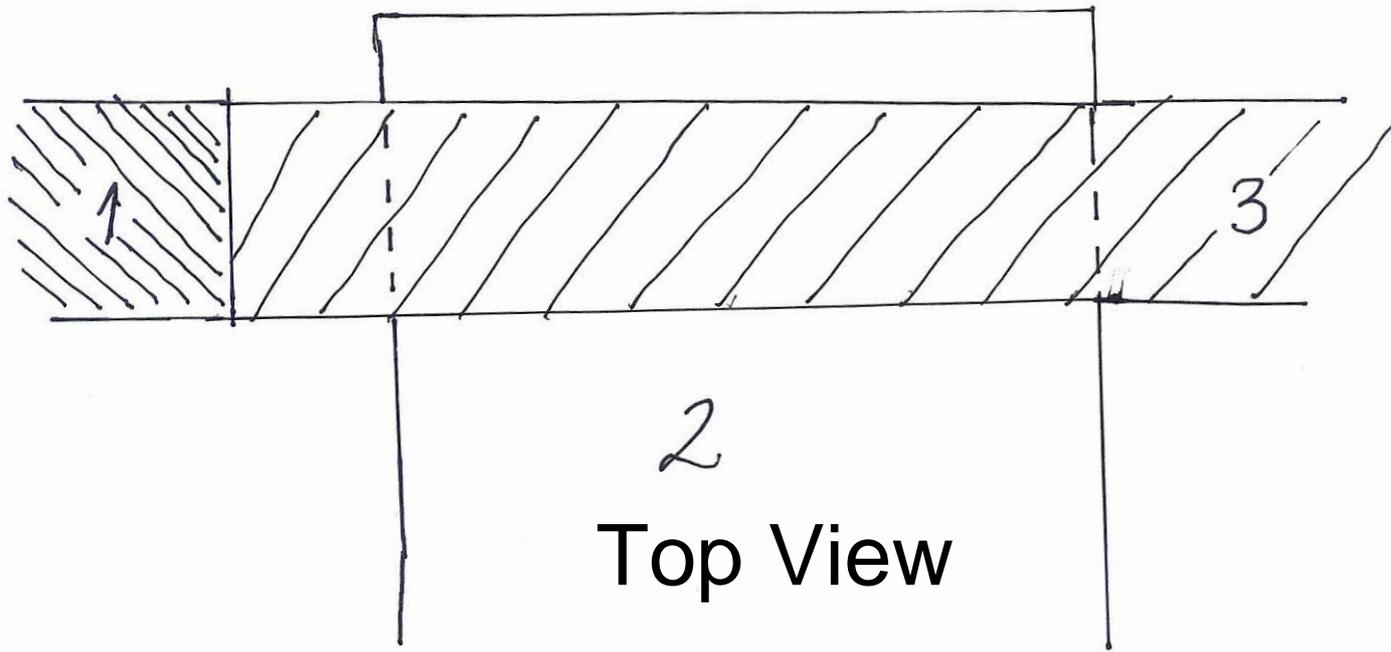
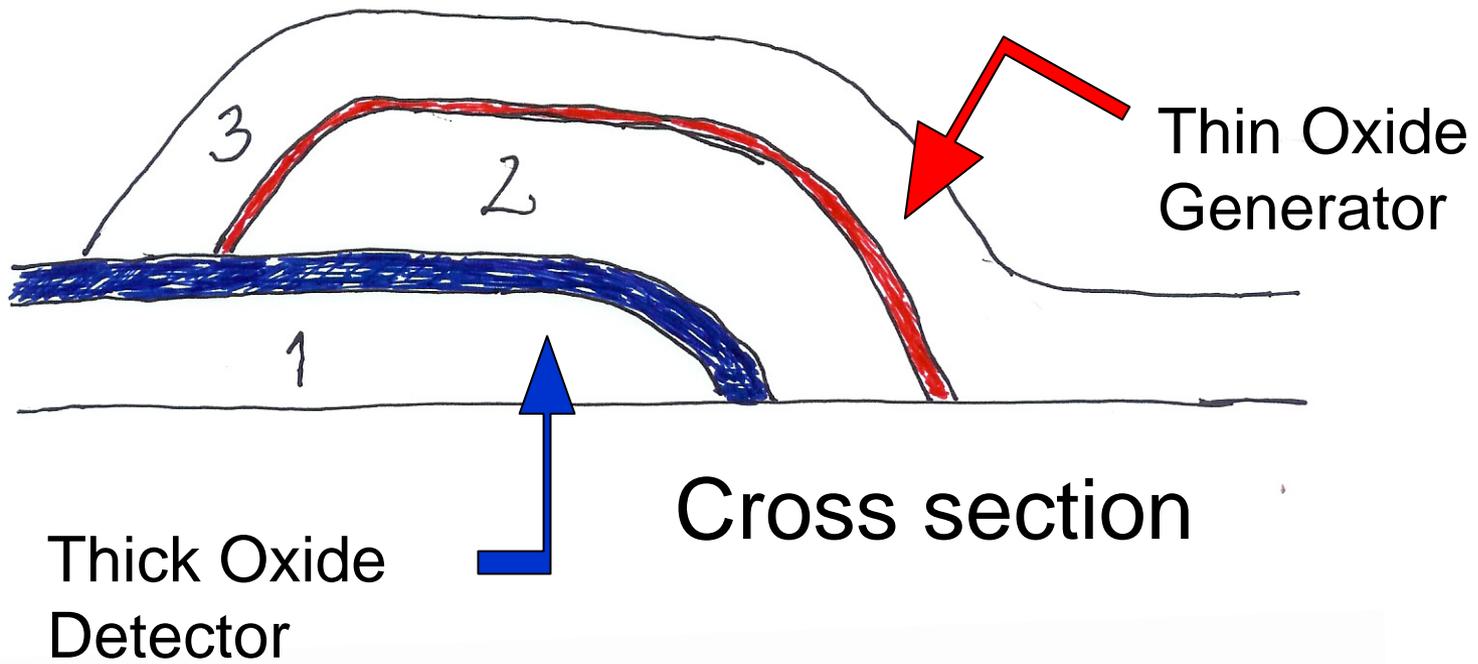


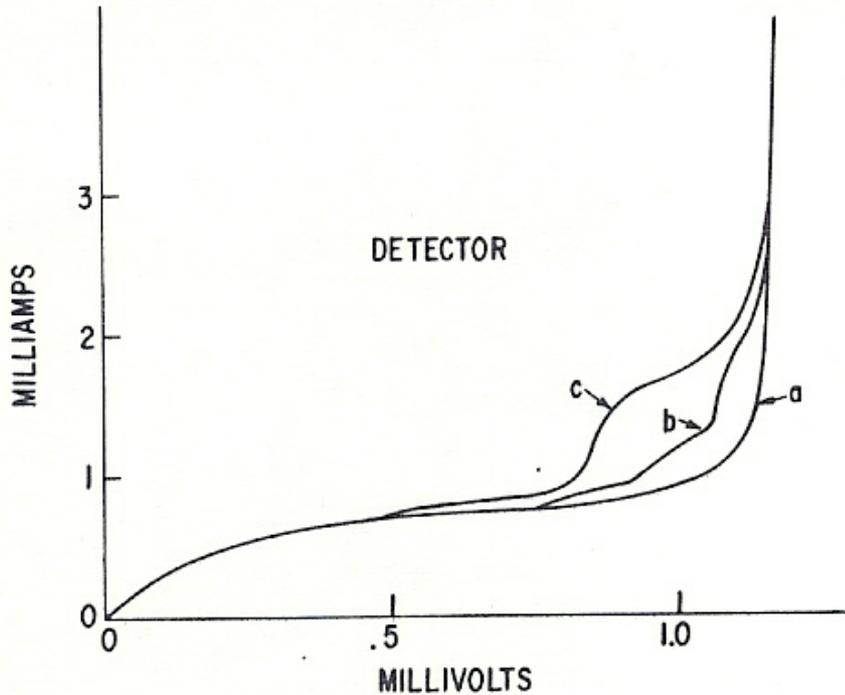
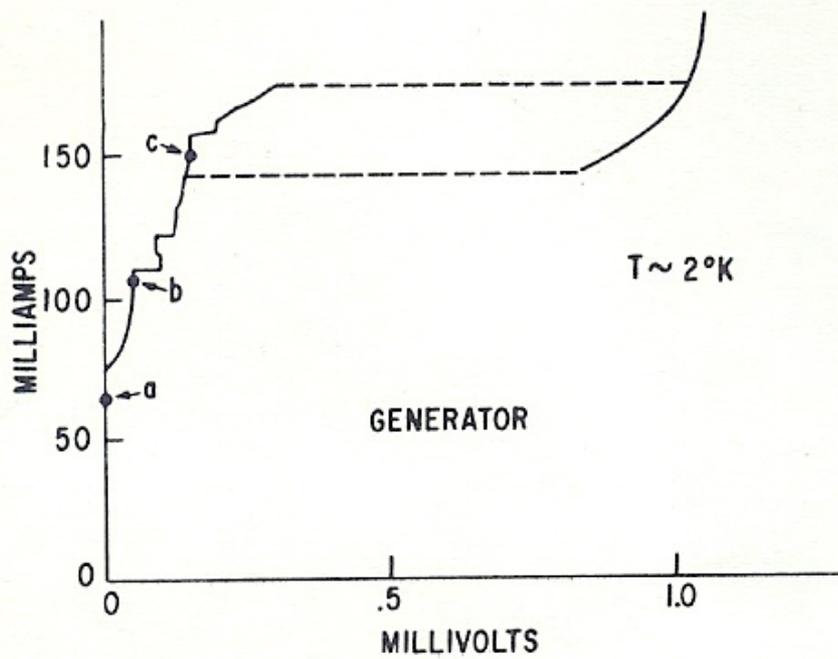
Dayem &
Martin

Phys.Rev.Lett
246-248 1962

Low
frequency







Note the high current in the generator compared to the detector

To receive a Nobel Medal you must:

be curious

be competitive

be creative

be stubborn

be self confident

be skeptical

be patient

And above all you must

be **LUCKY**

