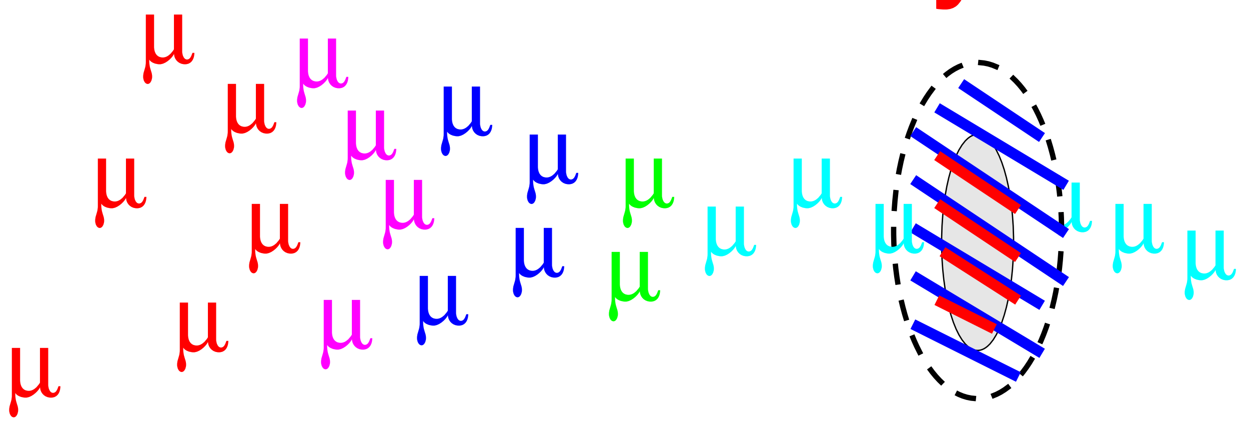
University of Chicago

Beam Profiling:

Bolometry Works!



Faculty: Mark Oreglia

Research Associate: Kara Hoffman

Students: David Billmire Eric Switzer
Karen Kasza

Technical support: Elizabeth Pod (mechanical)
Harold Sanders (electronics)
Mircea Bogdan (electronics)

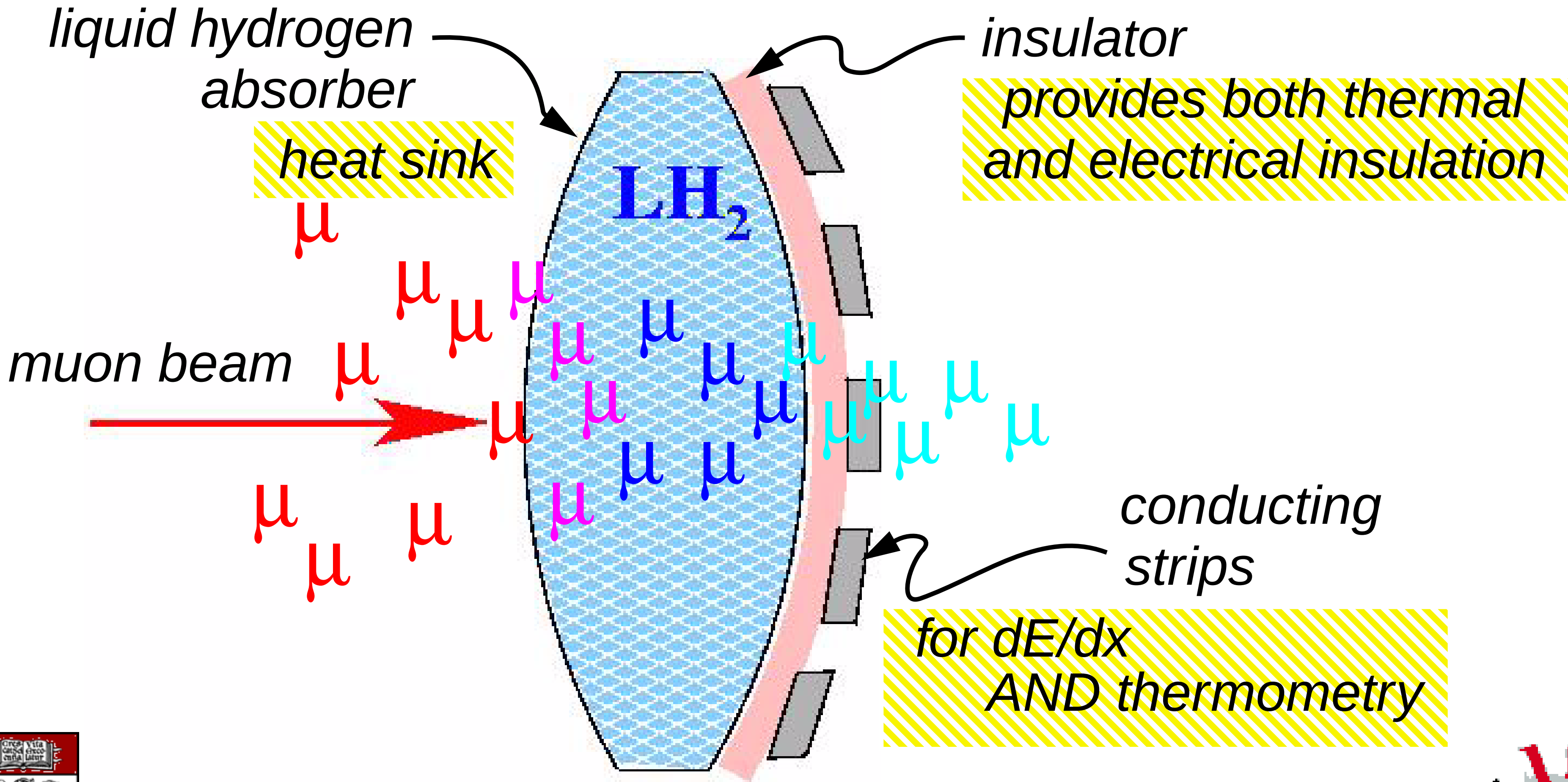
BOLOMETRY

1) muons traverse bolometric strips, depositing energy

2) deposited dE/dx heats the strip

3) muon is detected through change in voltage on strip because resistance of strip is temperature sensitive

4) hydrogen absorber serves as heat sink to cool strip



AN ELEGANT SOLUTION

...for detection and profiling of the muon beam

advantages

Minimal amount of material in the path of the beam.

Existing liquid hydrogen used for cooling doubles as an absorber.

Sensitive only to high energy particles, not noise from low energy background.

challenges

Finding the optimal media for bolometry and insulation.

Fabrication.

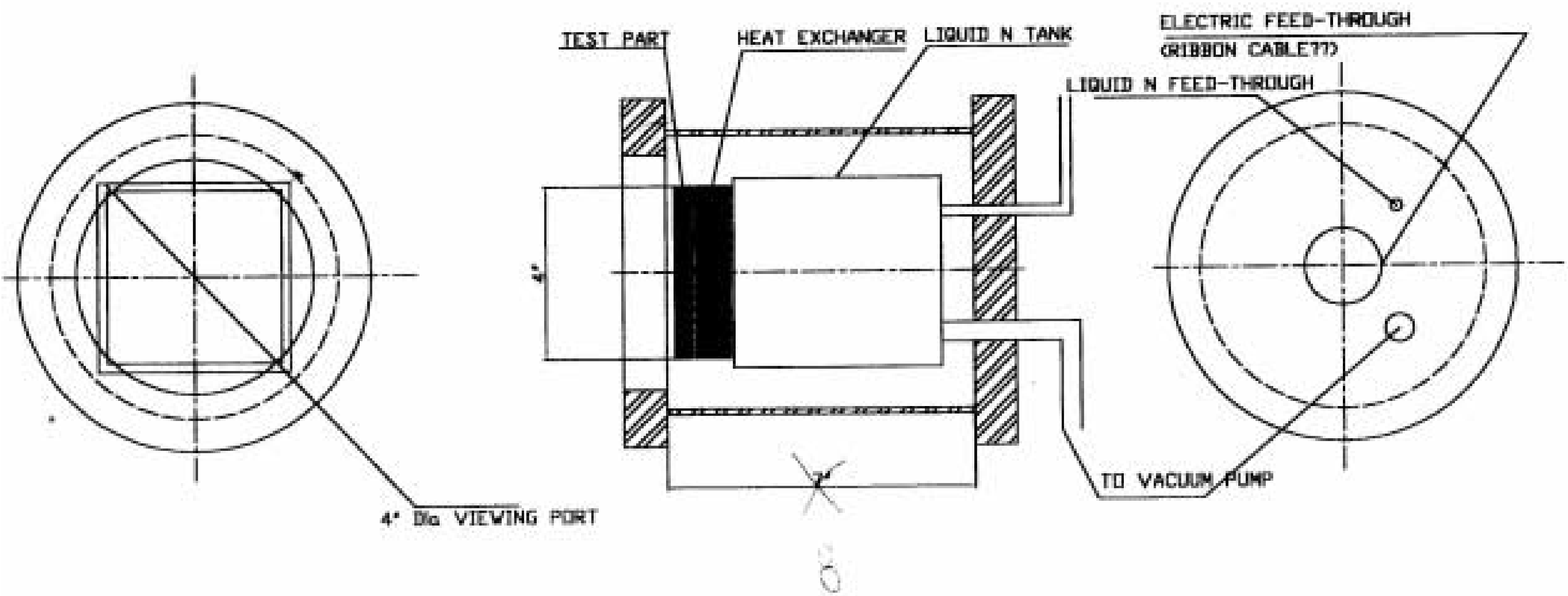
Designing electronics with high gain, high bandwidth, and very low noise.

PROOF OF PRINCIPLE TEST

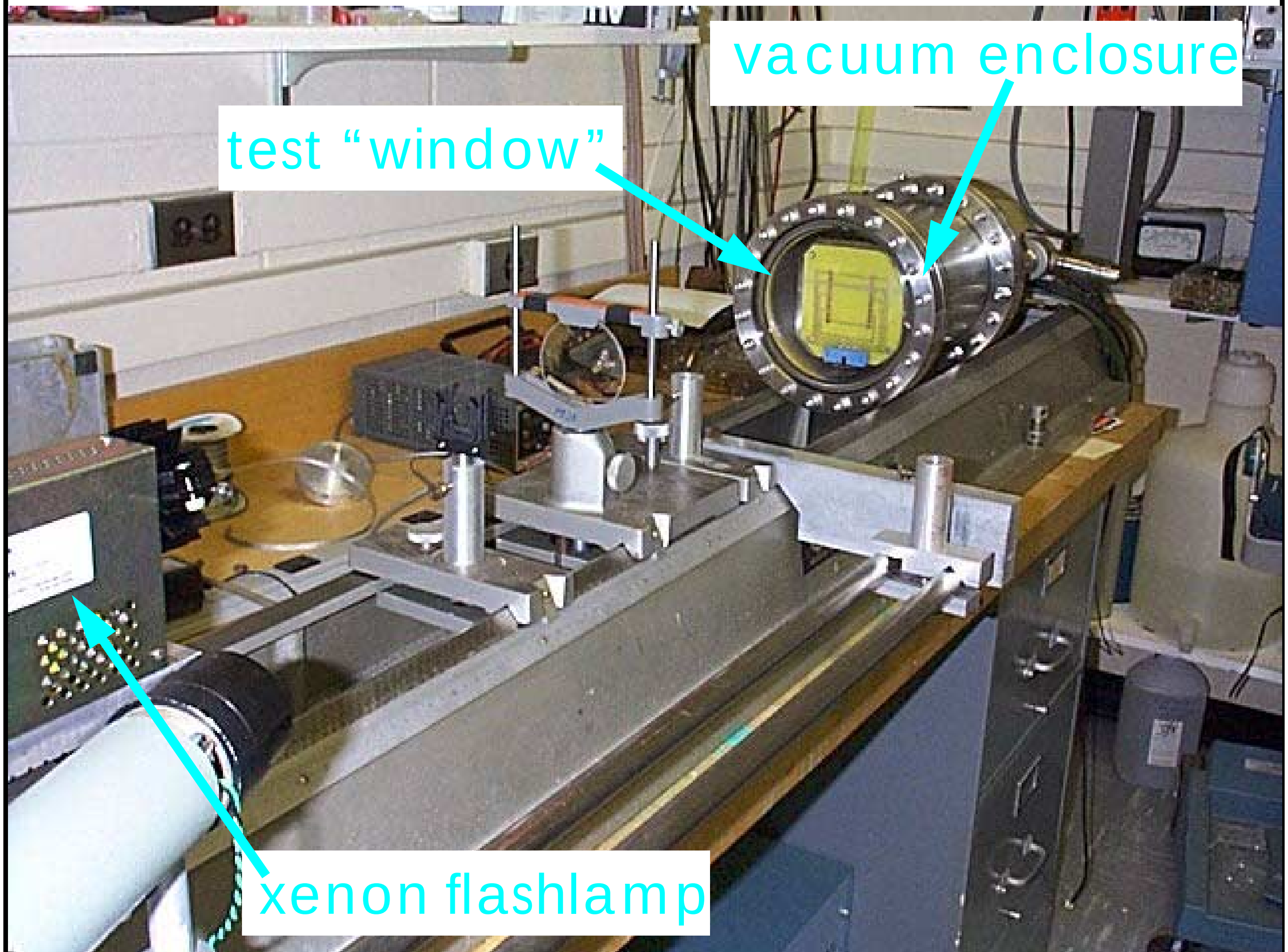
A test "window" has been constructed at U of C to demonstrate that bolometry works.

It is cooled with liquid nitrogen.

Beam pulses simulated with a xenon flashlamp.



Test Setup



-measurements were made at ~40 millitorr and at atmospheric pressure

-measurements were made at liquid nitrogen and room temperature

-for ease of changing samples, “bolometers” were taped, not glued. Better thermal contact could certainly be achieved.

ELECTRONICS

- Must have very low current (so electric power dissipation does not heat strips, obscuring measurement)

-We are studying commercially available instrumentation amplifiers

  - must have large gain (~1000)
  - must have a large bandwidth
  - must have very low noise

-We have a circuit based on a wheatstone bridge using a MAXIM 4145 differential instrumentation amplifier.

BOLOMETRIC MATERIAL

Requirements

-must be high Z

muon must deposit measurable dE/dx

-must have a large TCR curve near liquid hydrogen temperatures

must be sensitive to small changes in T

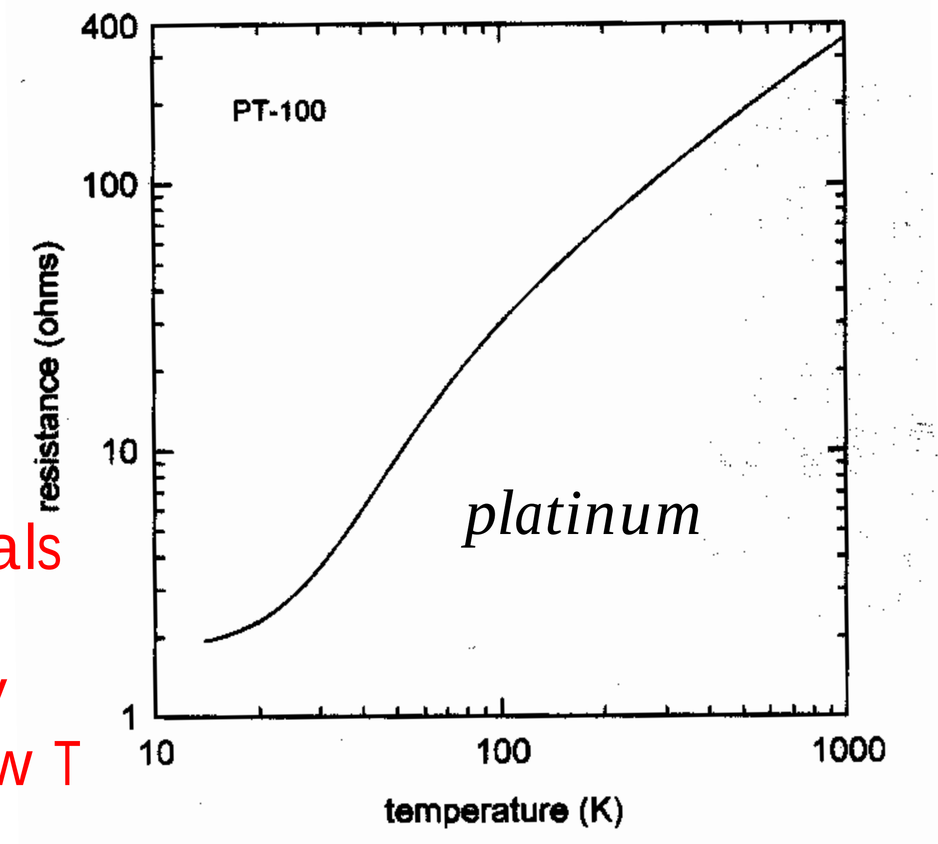
-must be radiation hard

Pure metals

often used in thermometry

rad-hard

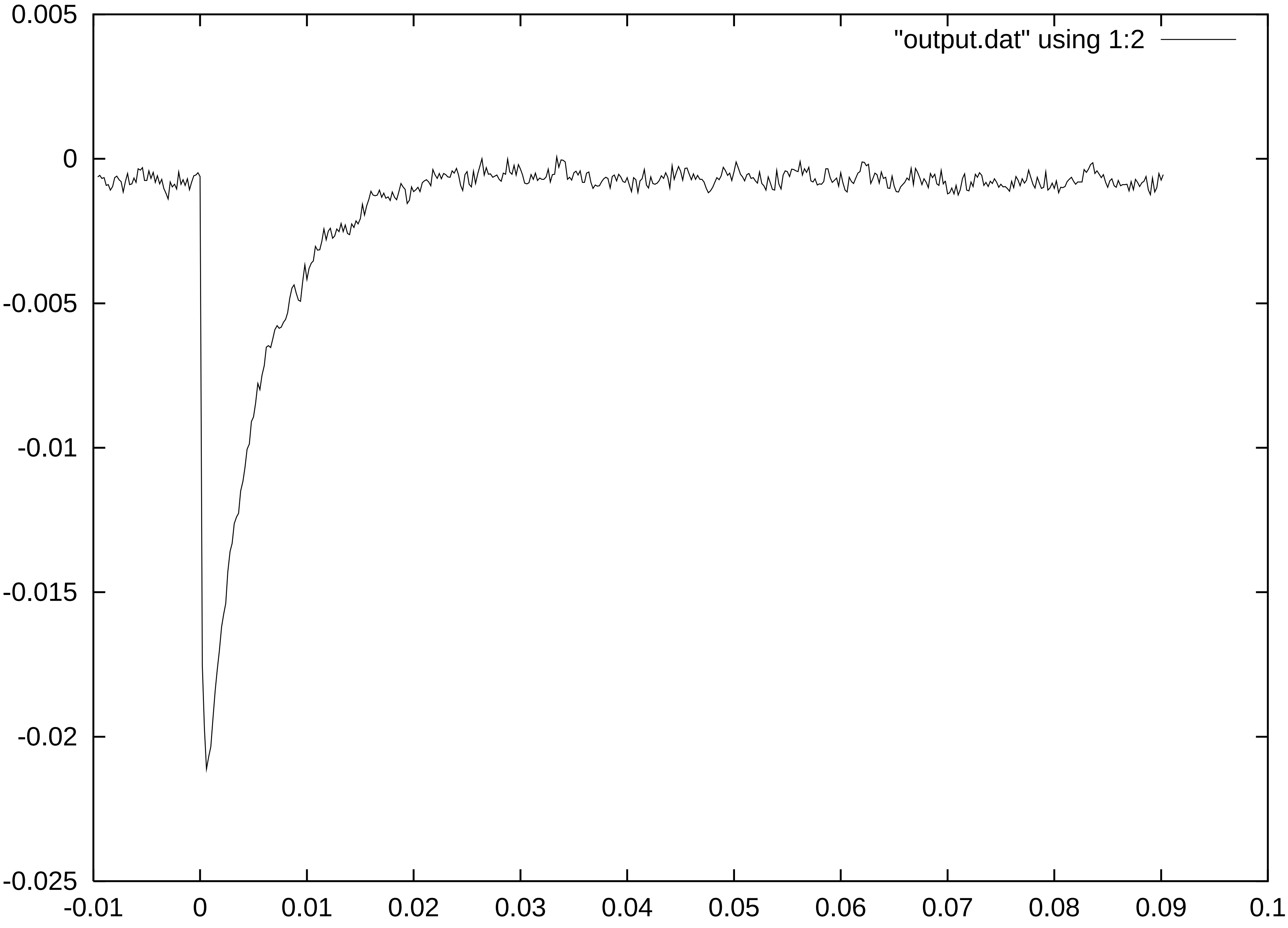
some pure metals dominated by electron-impuity scattering at low T



Other candidates:

- semiconductors (doped Ge)
- alloys
- disordered materials
- superconductors

PROOF OF PRINCIPLE: GRAPHITE


"output.dat" using 1:2
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1

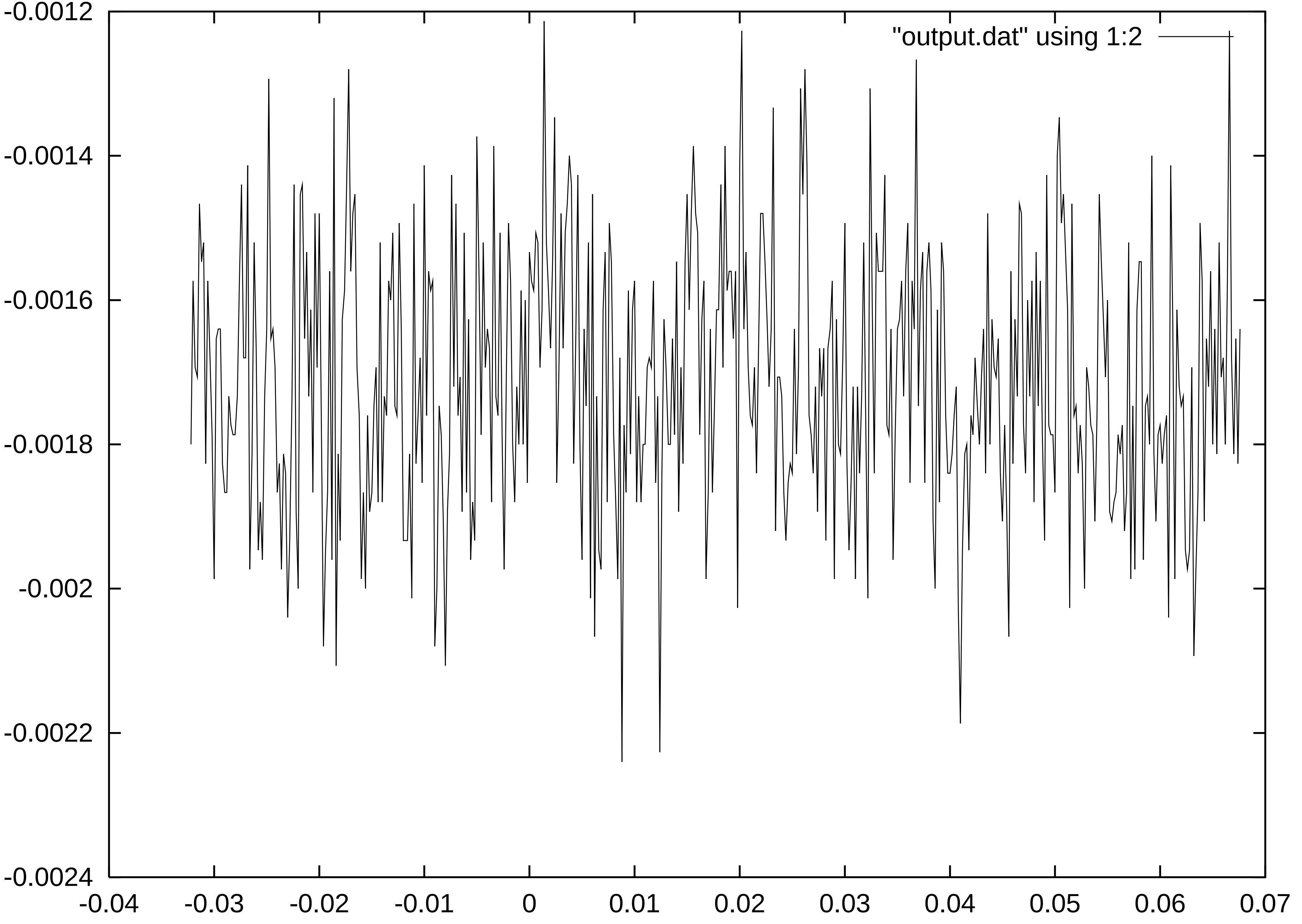
CONSTANTAN GUAGE

Strain gauges operate on a similar principle to bolometers...

-bolometers change resistivity in response to changes in temperature.

-strain gauges change resistivity in response to deformation

No sensitivity.

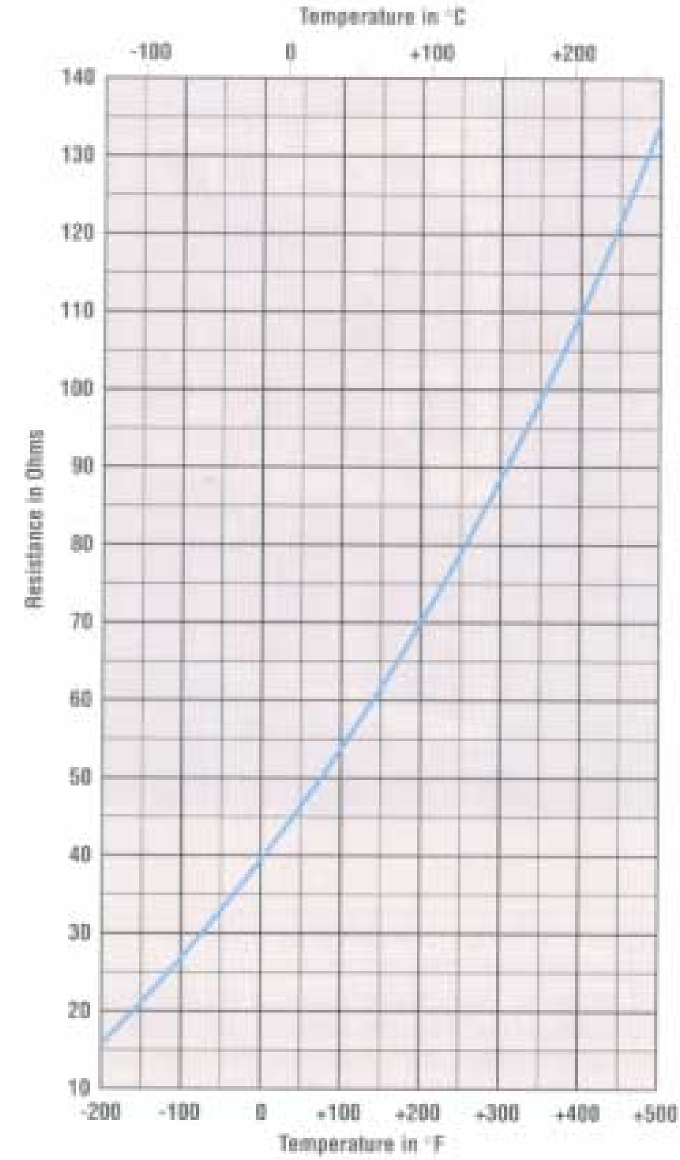

"output.dat" using 1:2
-0.0012
-0.0014
-0.0016
-0.0018
-0.002
-0.0022
-0.0024
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07

Commercial Nickel Thermometer

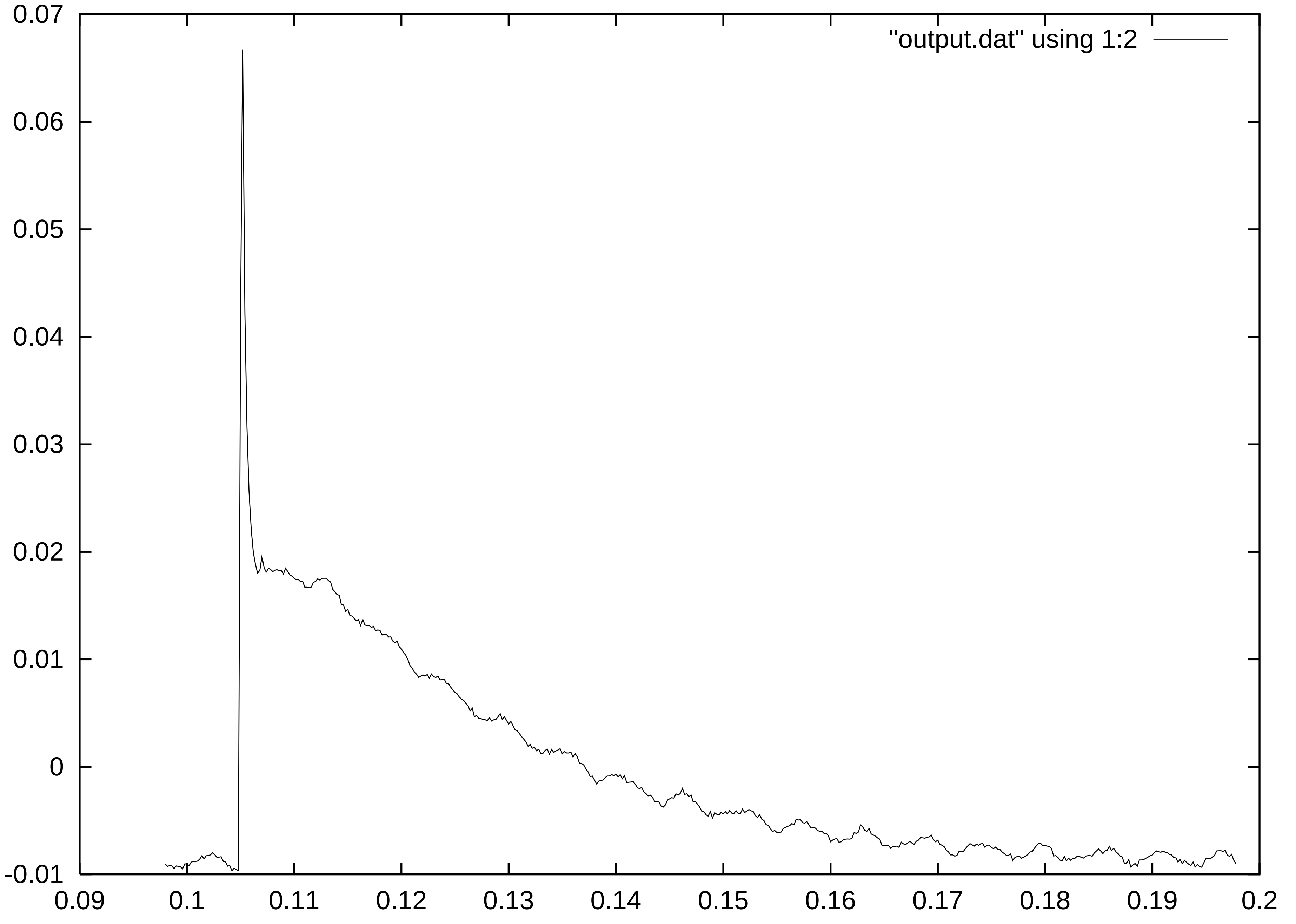
Measurements Group, however does make strain gauge style thin film thermometer.

Construction:
Nickel encapsulated in Kapton.

They also make custom gauges.



Typical data for 50Ω nickel sensor.

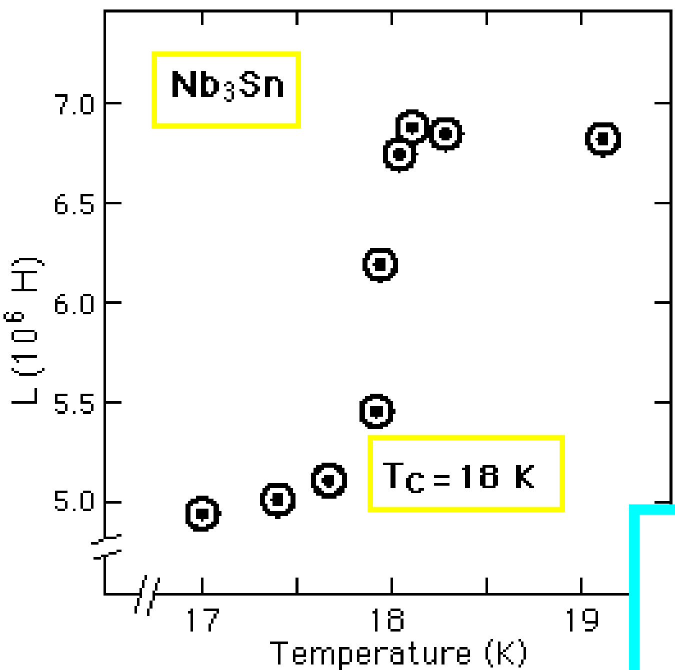

0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0.09
0.1
0.11
0.12
0.13
0.14
0.15
0.16
0.17
0.18
0.19
0.2
"output.dat" using 1:2

SUPERCONDUCTORS?

Type II Superconductors:

-will superconduct in magnetic fields

-some have Tc near LH2 temperatures



Niobium Tin

Tc=18K

TCR slope may be tuned by adding impurities

(evaporable) easy fabrication?

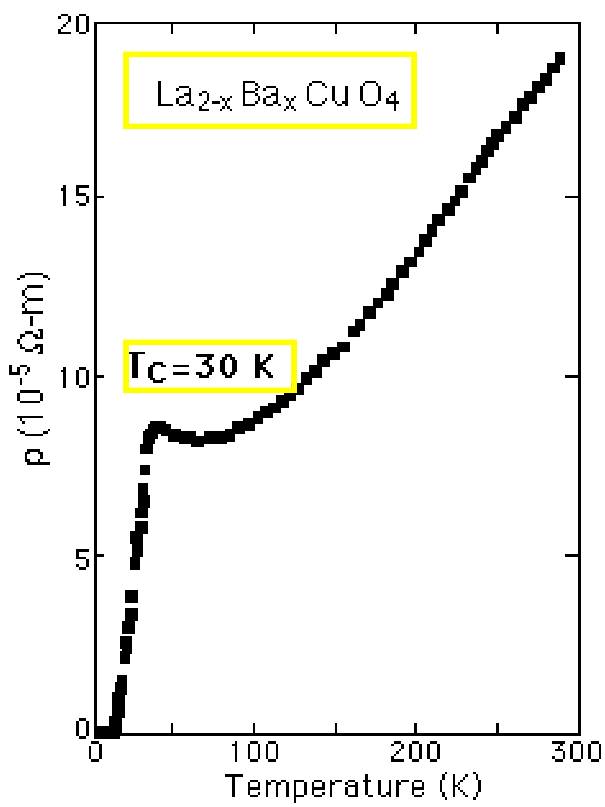
La-Ba-Cu-O

Tc=30K

ceramic

(may not be adequately rad-hard!)

may have to outsource fabrication



WHAT NEXT?

We have proof of principle (both at liquid nitrogen and room temperature)

We now need to develop instrumentation specific to our application.

Considerations:

- high TCR at liquid helium temperatures
- radiation hard
- must perform in magnetic fields
- noise: geometry of bolometer and final electronics must minimize noise