NTD-GERMANIUM-BASED X-RAY MICROCALORIMETERS

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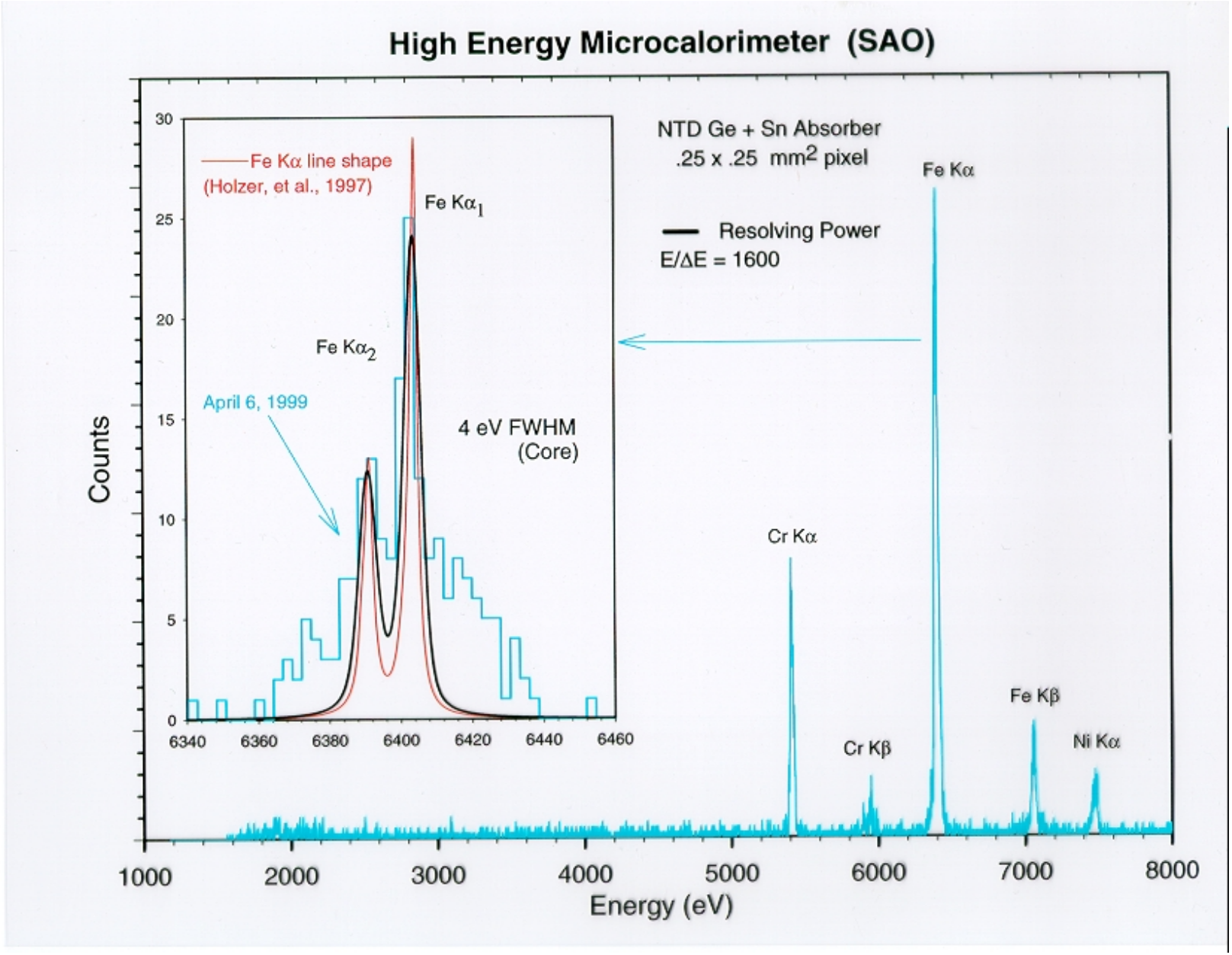
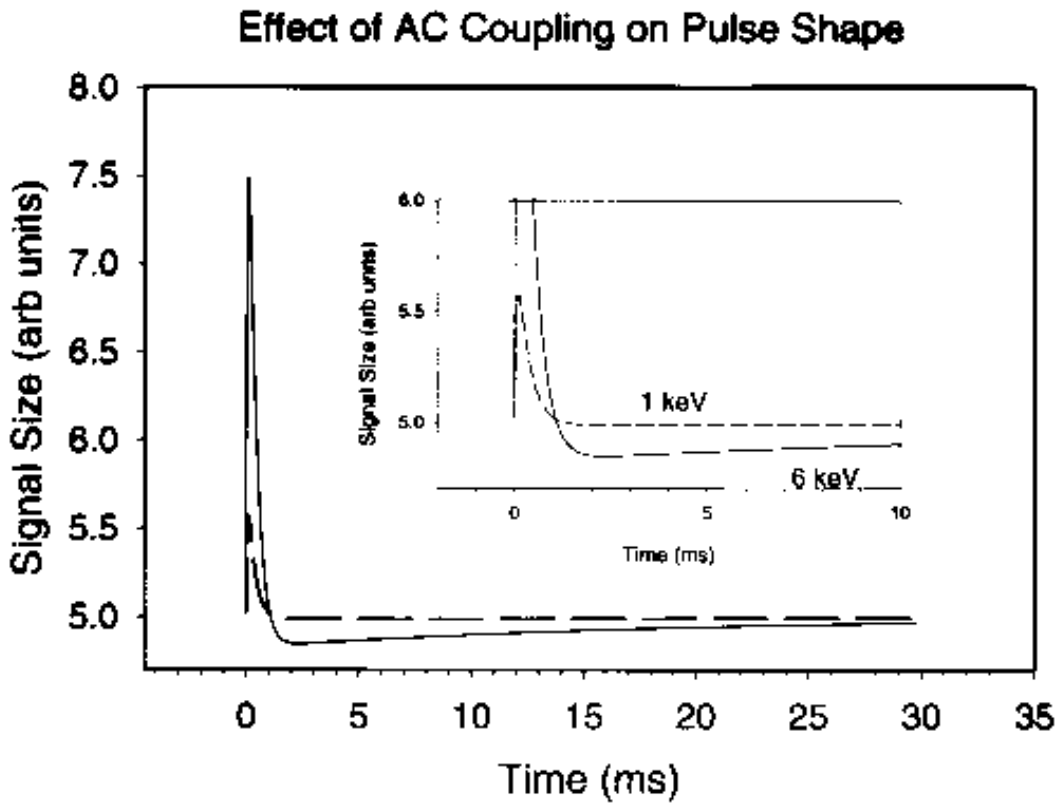
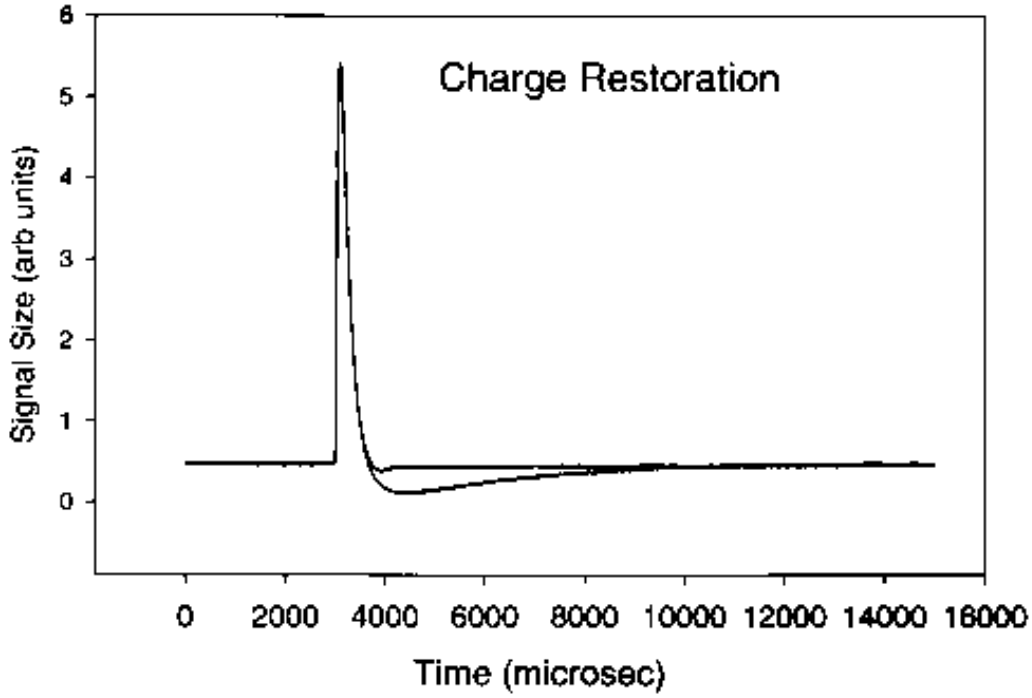
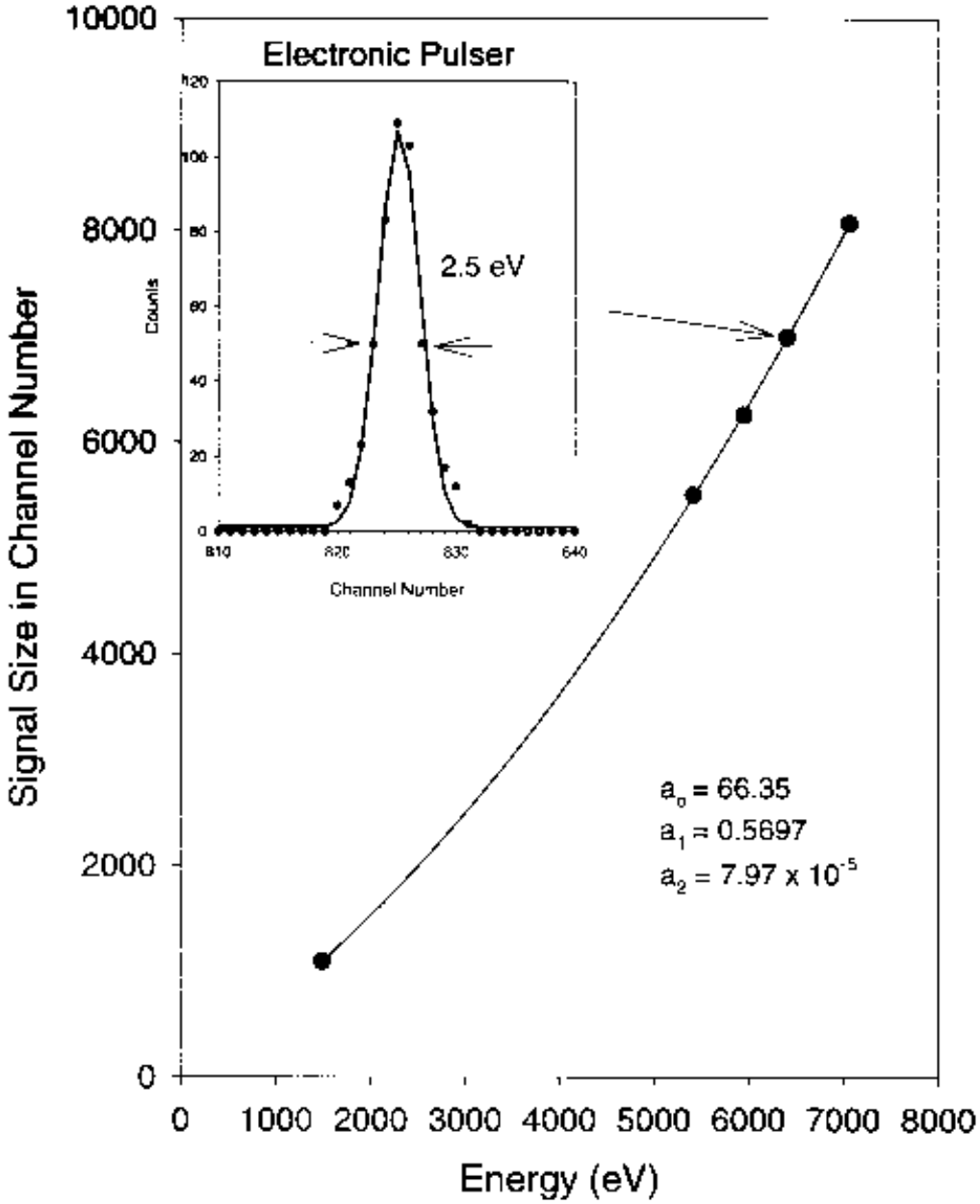
OUTLINE

- DEMONSTRATE THE PERFORMANCE OF OUR NTD-Ge MICROCALORIMETERS
  - PRESENT SOME RECENT RESULTS FROM LABORATORY ASTROPHYSICS EXPERIMENTS AT NIST, GAITHERSBURG
  - TANTALIZING HINTS OF WHAT WE CAN EXPECT FROM THE μCALS ON ASTRO-E + CON-X
- REVIEW OUR WORK ON IMPROVING SINGLE PIXEL ENERGY RESOLUTION
- PRELIMINARY ARRAY DEVELOPMENT
  - MODULAR CONSTRUCTION FROM BULK NTD Ge
  - THIN-FILM, MONOLITHIC CONSTRUCTION

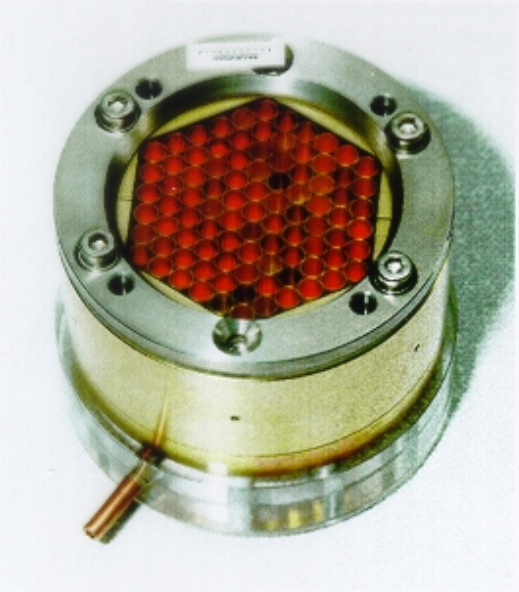

High Energy Microcalorimeter (SAO)
NTD Ge + Sn Absorber
.25 x .25 mm2 pixel
Resolving Power
E/ΔE = 1600
Fe Kα line shape
(Holzer, et al., 1997)
Fe Kα1
Fe Kα2
April 6, 1999
4 eV FWHM
(Core)
Cr Kα
Cr Kβ
Fe Kα
Fe Kβ
Ni Kα
Counts
Energy (eV)
1000
2000
3000
4000
5000
6000
7000
8000
0
5
10
15
20
25
30
6340
6360
6380
6400
6420
6440
6460


Effect of AC Coupling on Pulse Shape
Signal Size (arb units)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
0
5
10
15
20
25
30
35
Time (ms)
1 keV
6 keV
Signal Size (arb units)
6.0
5.5
5.0
0
5
10
Time (ms)

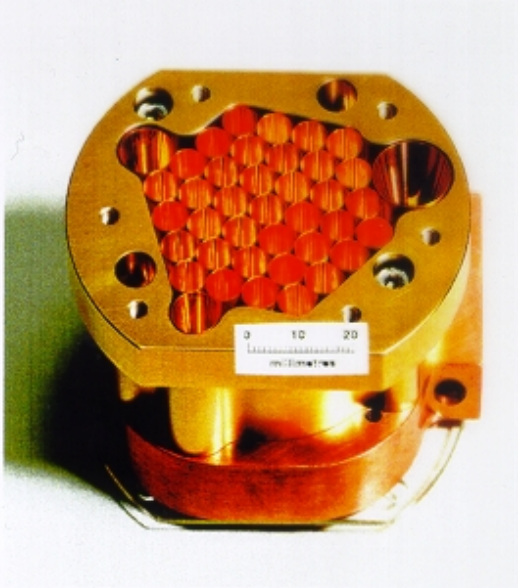

Charge Restoration
Signal Size (arb units)
6
5
4
3
2
1
0
0
2000
4000
6000
8000
10000
12000
14000
16000
Time (microsec)


Electronic Pulser
2.5 eV
Counts
Channel Number
Signal Size in Channel Number
Energy (eV)
a_0 = 66.35
a_1 = 0.5697
a_2 = 7.97 x 10^{-5}
0
2000
4000
6000
8000
10000
0
1000
2000
3000
4000
5000
6000
7000
8000

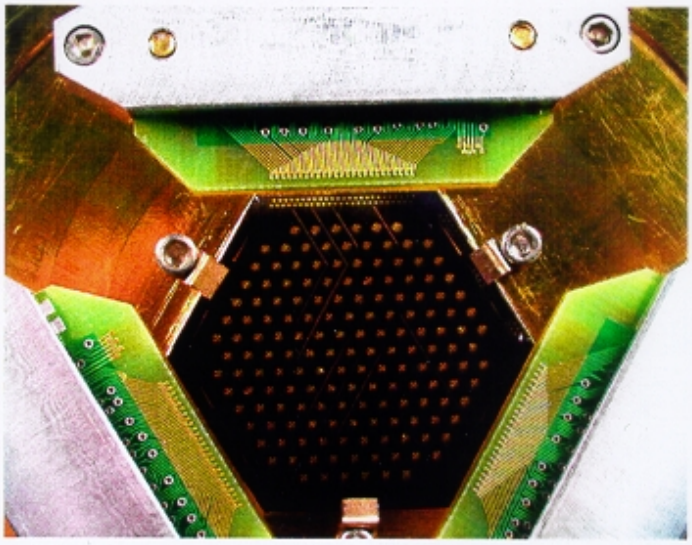
NTD Germanium Arrays



SCUBA 91 Element Array
(JCMT)

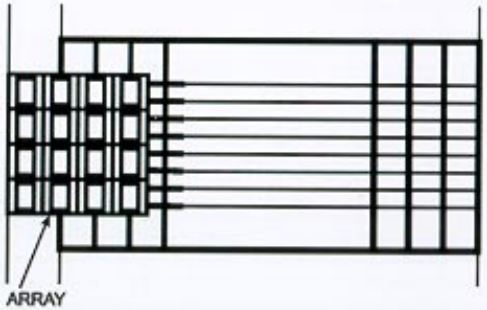


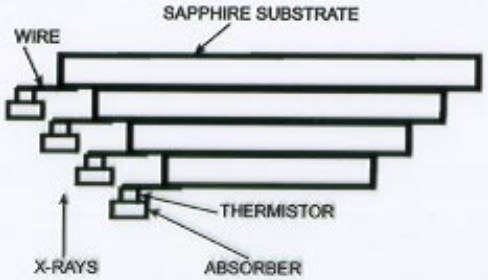
SCUBA 37 Element Array
(JCMT)

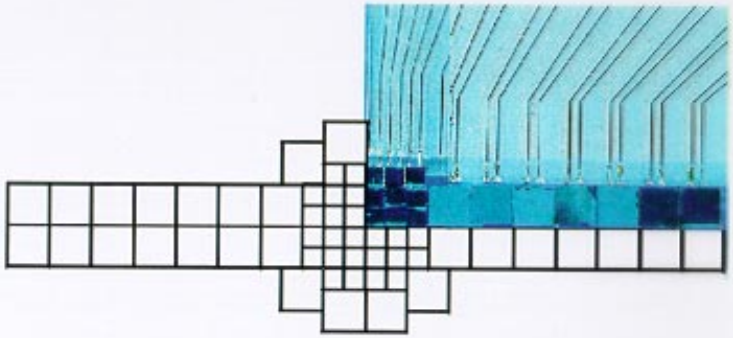


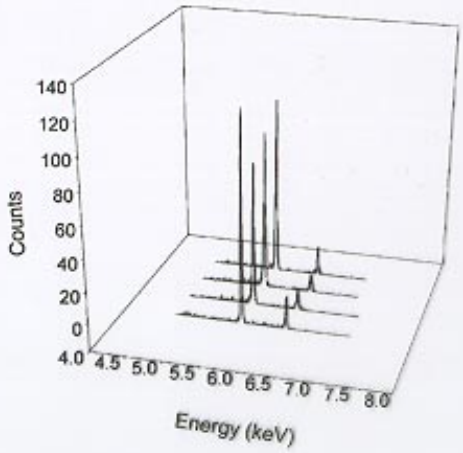
BOLOCAM (JPL)

NTD Germanium Array Development



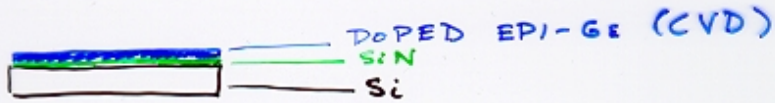






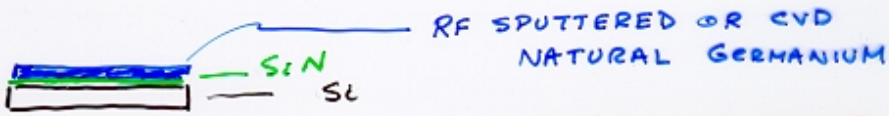
THIN-FILM GERMANIUM THERMISTORS

- DOPED EPITAXIAL GERMANIUM



USE PHOTOLITHOGRAPHIC TECHNIQUES TO PATTERN THERMISTORS & INTERCONNECTS

- THIN-FILM NTD GERMANIUM



- EXPOSE ENTIRE WAFER TO THERMAL NEUTRONS

SiN ≡ WIDE BANDGAP INSULATOR → NOT DOPED VIA THERMAL NEUTRON CAPTURE

Si WAFER → SLIGHTLY PHOSPHORUS DOPED BUT AT SIGNIFICANTLY LOWER CONCENTRATION THAN Ga + As IN Ge FILM

- IN Si → ONLY 3.2% ^{30}Si TRANSMUTES INTO ^{31}P & CROSS-SECTION ≈ $1.1 \times 10^{-26}\ cm^2$
  → $3.25 \times 10^{-24}\ cm^2$ FOR ^{70}Ge (20.5%) + $5.2 \times 10^{-25}\ cm^2$ FOR ^{74}Ge (36.5%)

PROCEDURE:

1. SPUTTER 0.5 + 5 μm Ge (ARGON PLASMA) ONTO AMORPHOUS SiN-COATED Si WAFERS
   - CHARACTERIZE ELECTRICAL PROPERTIES

2. RAPID THERMAL ANNEALING IN 500-800°C TO CRYSTALIZE TEST SAMPLES
   PRELIM. TESTS SHOW SUCCESSFUL CRYSTALLIZATION > 600-650°C IN A N_2 ATMOSPHERE

3. ION-IMPLANT TEST FILMS WITH B^+ AT SEVERAL ENERGIES TO DETERMINE DOPANT CONCENTRATION NEEDED FOR LOW TEMP WORK
   MEASURE R VS T + $\frac{1}{R}\frac{dR}{dT}$.

4. ESTIMATE THERMAL NEUTRON DOSE NEEDED TO PRODUCE DESIRED DOPANT DENSITY FOR CRYOGENIC THERMISTORS

5. EXPOSE TO NEUTRONS

6. TEST!

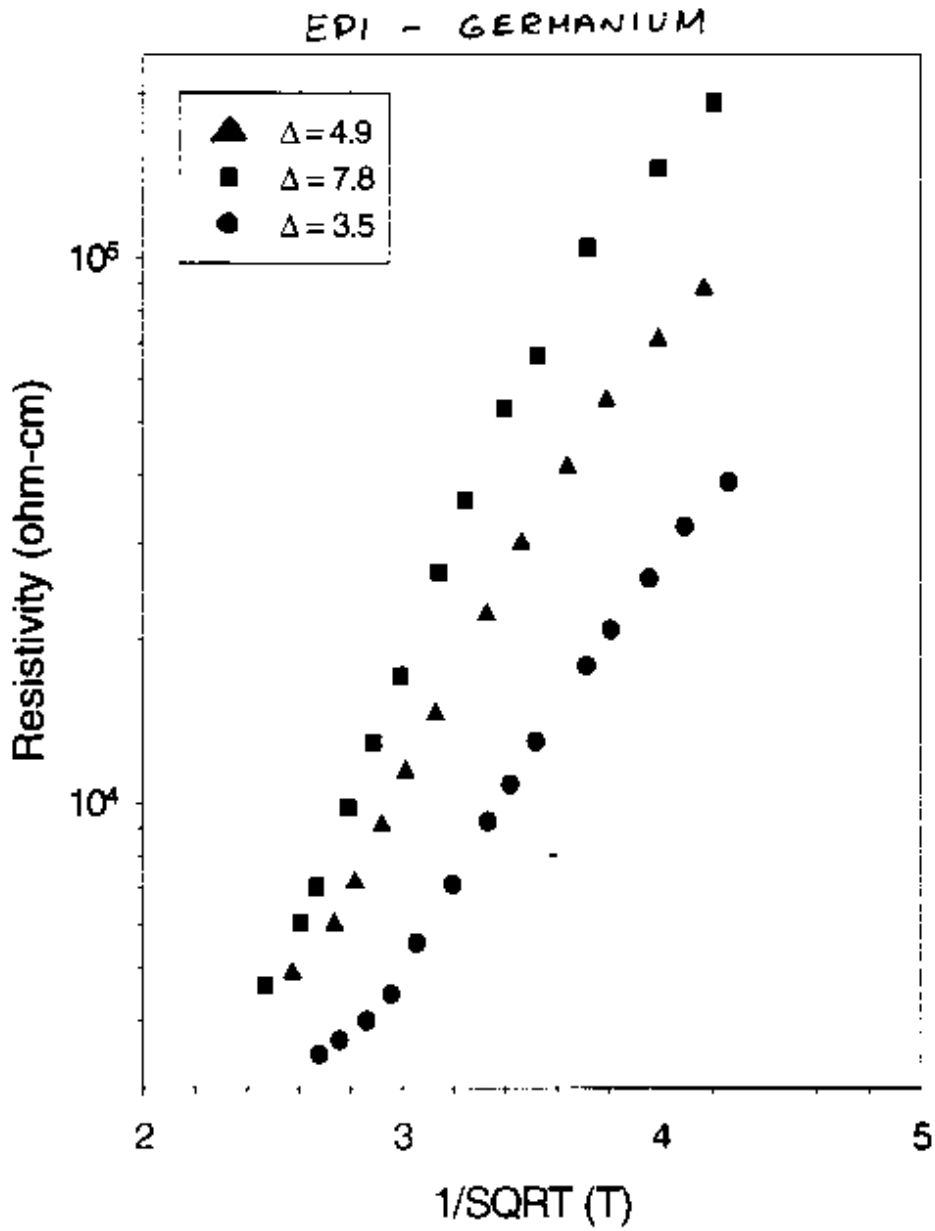


Fig. 4.6 : Resistivity of three samples of epitaxial germanium ▲= 2.0x10[illegible]As & 7.2x10[illegible]B; ●= 2.2 x10[illegible] As & 7.5x10[illegible] B; ■= 2.2x10[illegible] As & 7.5x10[illegible]B.

Multiplexing Semiconductor-Based Microcalorimeters

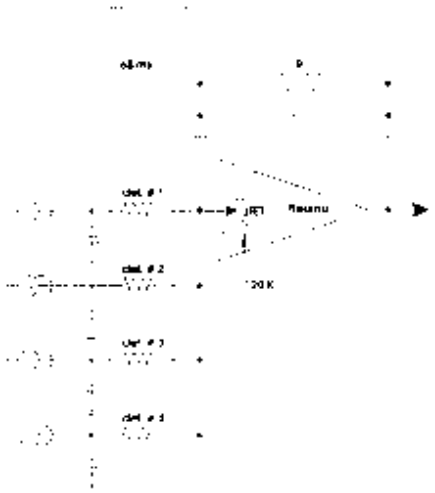


Figure 1. Detector multiplexing scheme

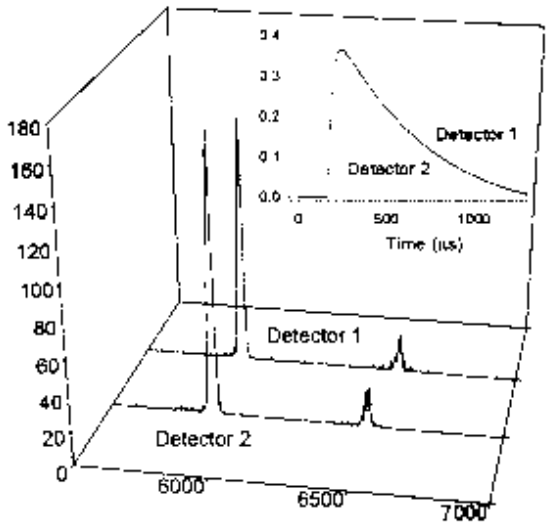


Figure 2.Mn K spectra for two multiplexed microcalorimeters. The inset shows the difference in thermal recovery time for the two detectors