N90-21315

IR Detector Technology Workshop
Feb. 7 – 9, 1989
NASA Ames Research Center

Stressed Ge:Ga Photoconductors for Space–Based Astronomy

(Is There Life Beyond 120 μm?)

J.W. Beeman	Lawrence Berkeley Laboratory
E.E. Haller	U. C. Berkeley and Lawrence Berkeley Laboratory
W.L. Hansen	Lawrence Berkeley Laboratory
P.N. Luke	Lawrence Berkeley Laboratory
P.L. Richards	U. C. Berkeley and Lawrence Berkeley Laboratory

INTRODUCTION

- material changes & wavelength shift
- stress aparatus considerations

AMOUNT OF STRESS

- measurement of applied stress
- determining the correct amount

STRESSED DETECTORS IN SPACE

- materials for low dark currents
- responsivity and NEP
- remaining problems

CONCLUSIONS

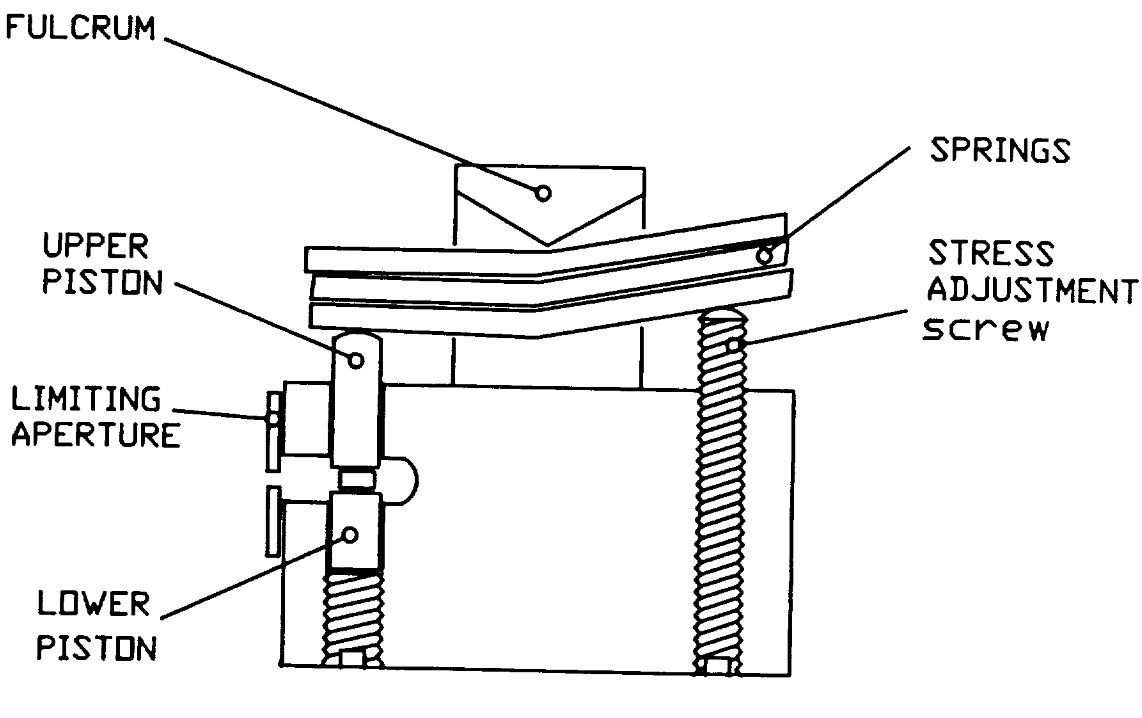
STRESSED Ge:Ga

- stress along [100] axis strains chemical bonds in lattice

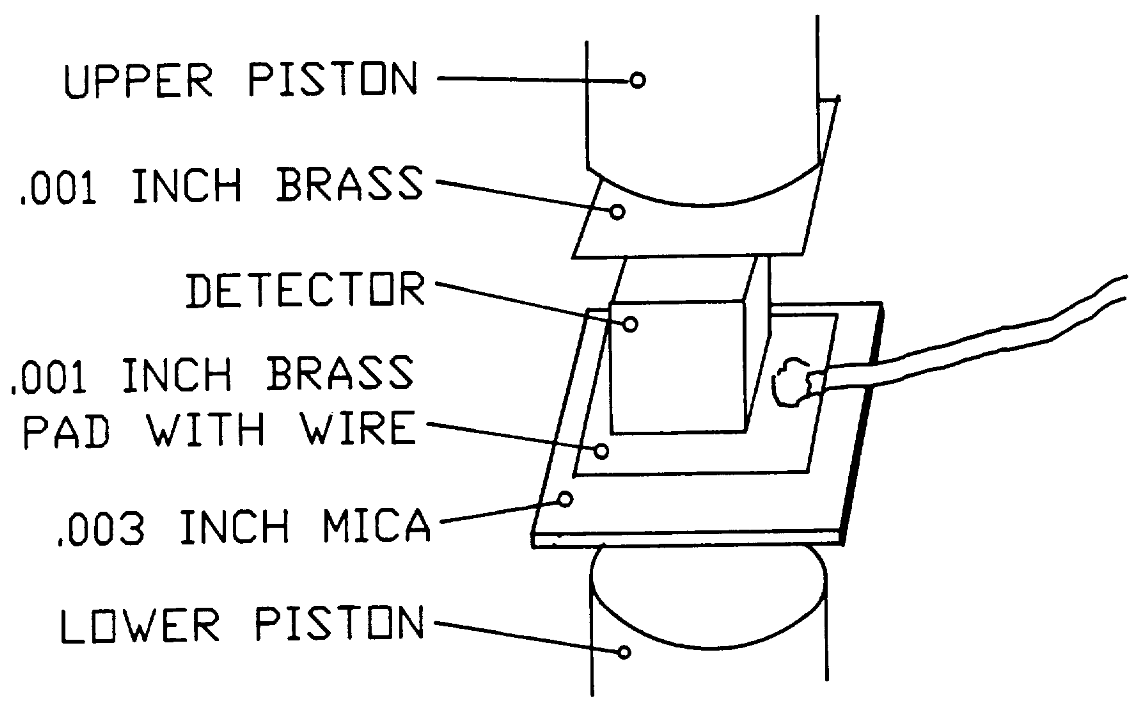
- reduces binding energy of holes

- detector becomes sensitive to lower energy photons

STRESS CAVITY CROSS SECTION



STRESSED DETECTOR MOUNTING DETAILS



SPRING-TYPE STRESS CAVITY

- a "large" spring deflection minimizes stress changes on cooling

- no torque is applied to chip... all stress is on-axis

- reflecting cavity with limiting aperture accommodates easy photon flux calculations

MOUNTING HARDWARE

- brass pads deform to aid in stress uniformity, but do not over-extrude

- mica pad ensures electrical isolation from cavity

    * high compressional resilience, does not deform

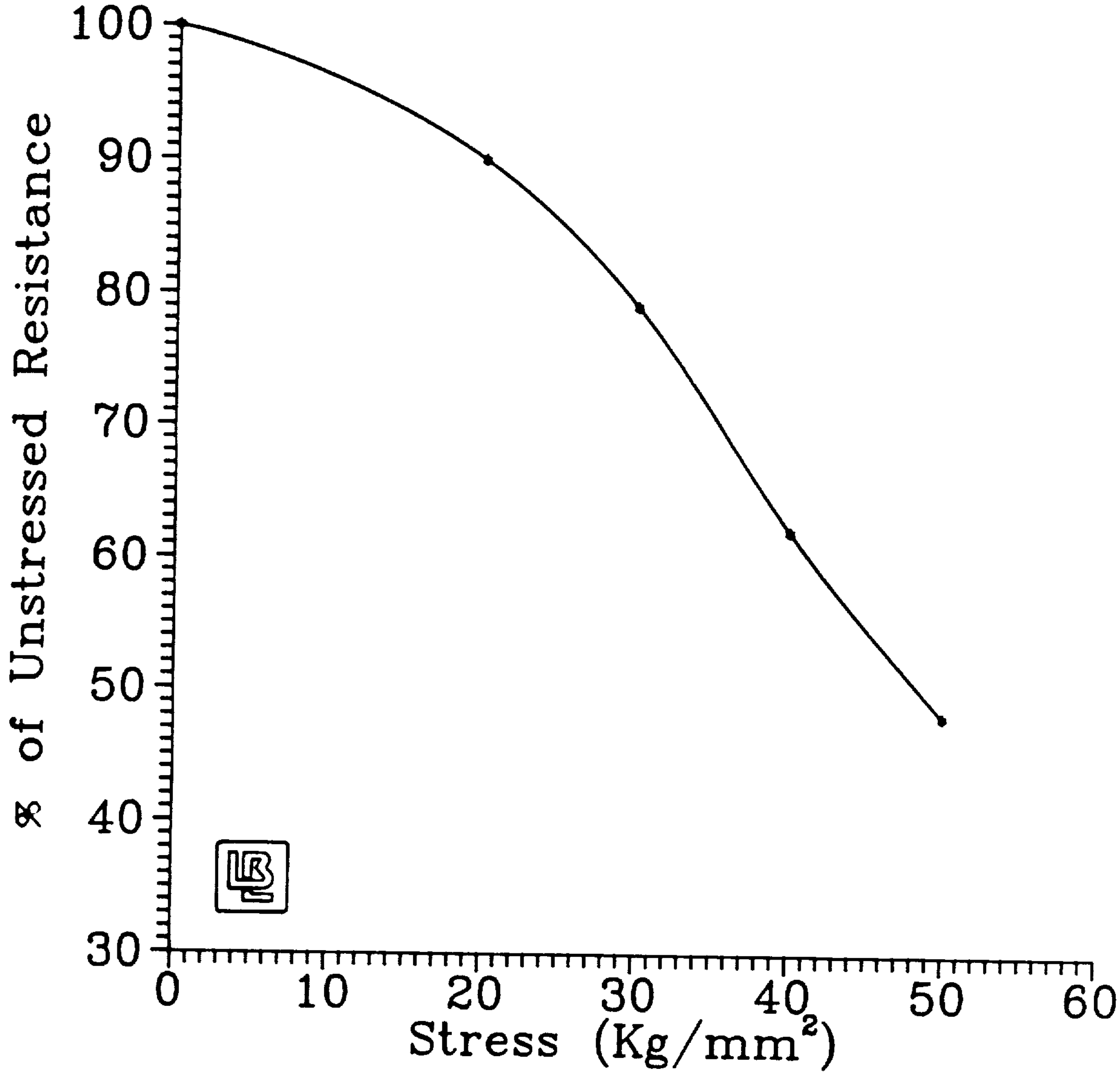
    * highly planar: keeps stress on-axis

AMOUNT OF STRESS

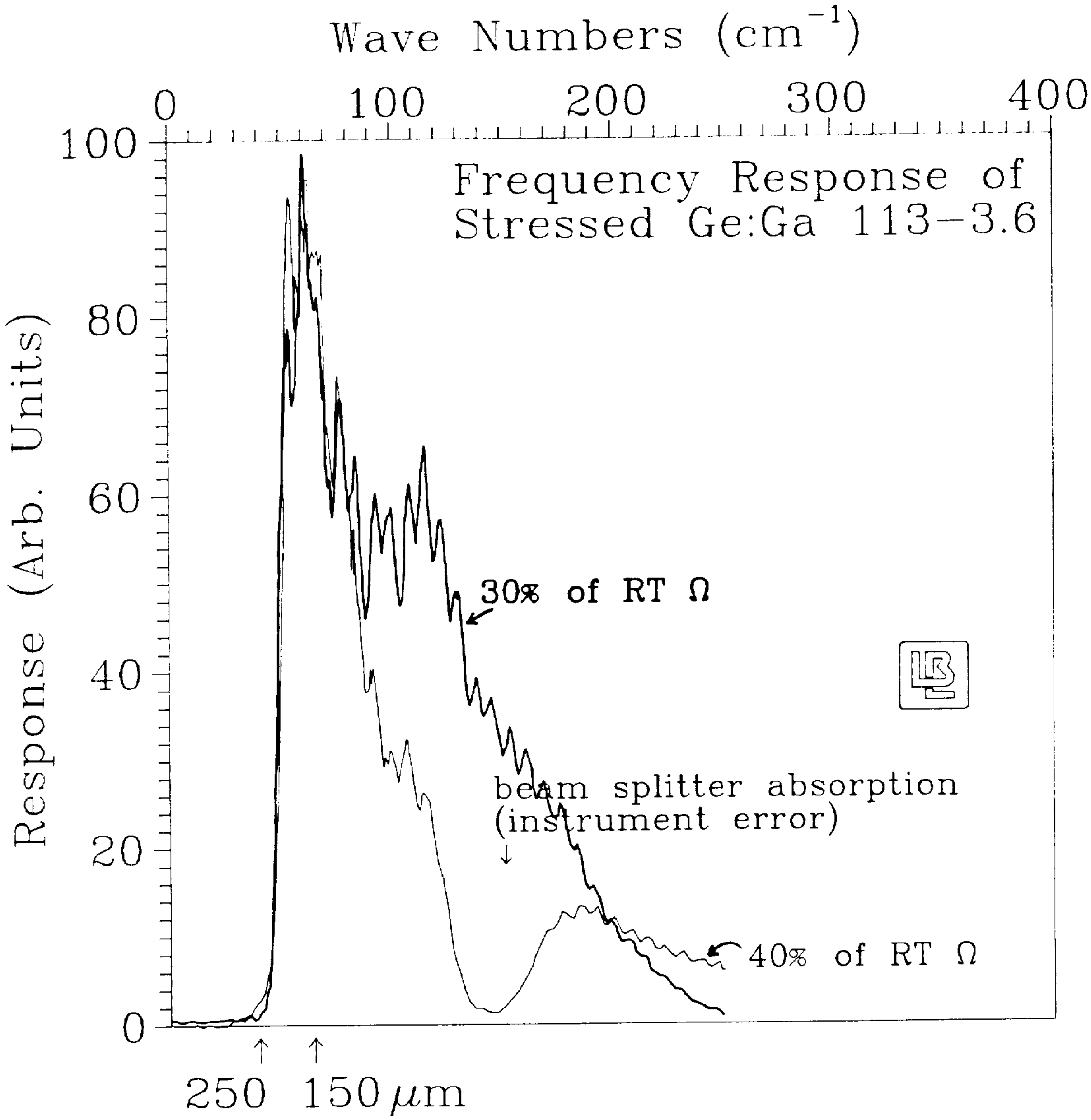
- the mobility of carriers increases with stress, therefore we need only monitor the detector's room temperature resistance to measure the applied stress

- the hole binding energy is an inverse function of stress. The minimum binding energy is approached asymptotically

- when the detector's room temperature resistance is reduced to 40% of its unstressed value, we have attained >90% of the possible binding energy reduction



The change in resistance of Ge:Ga (100) as a function of stress (room temperature)



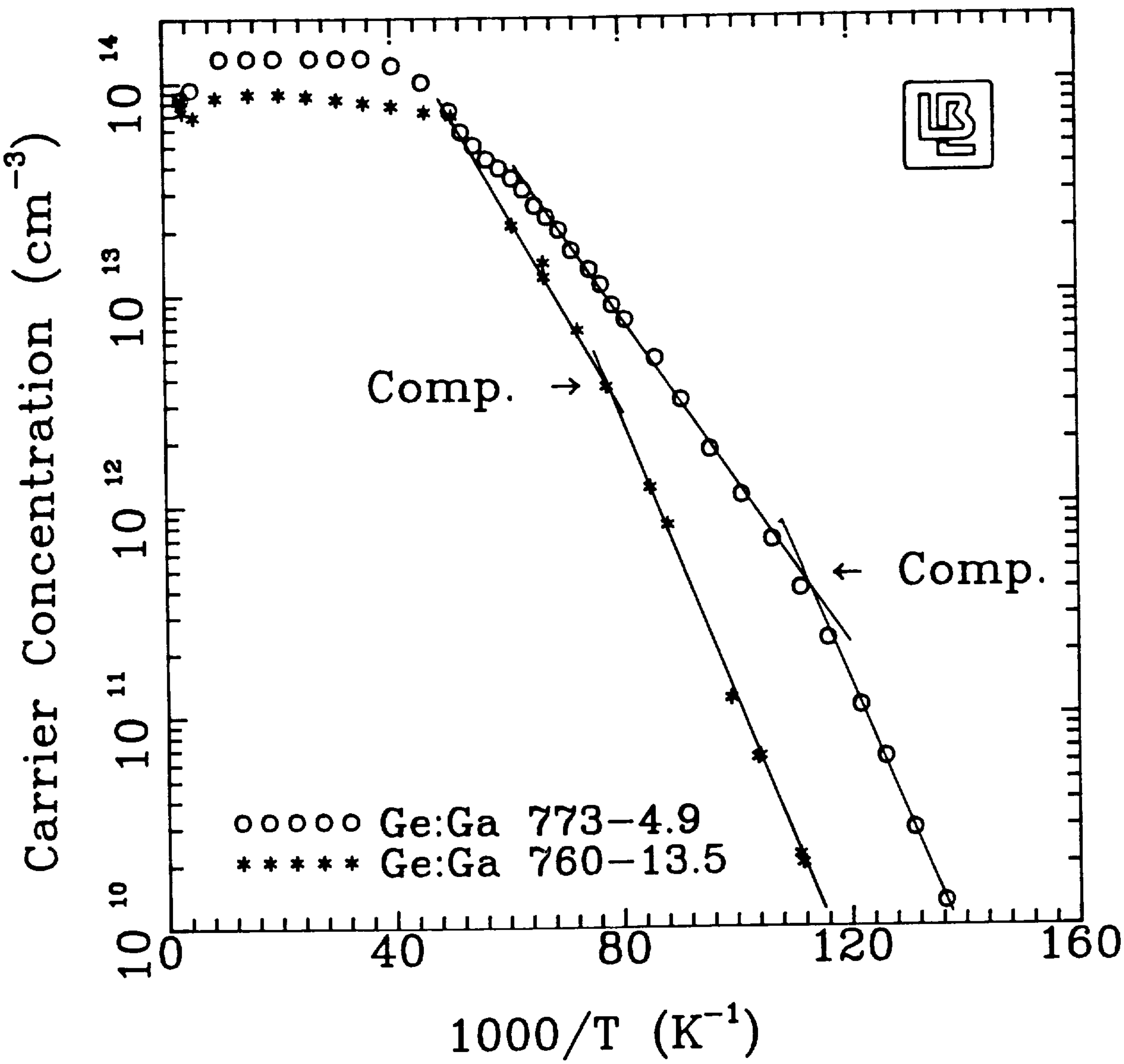
Detector response as a function of wavelength. Long wavelength extension saturates at 40% RT Ω. Additional stress (30% curve) does not further extend long wavelength response.

MATERIALS PARAMETERS AFFECTING DARK CURRENT

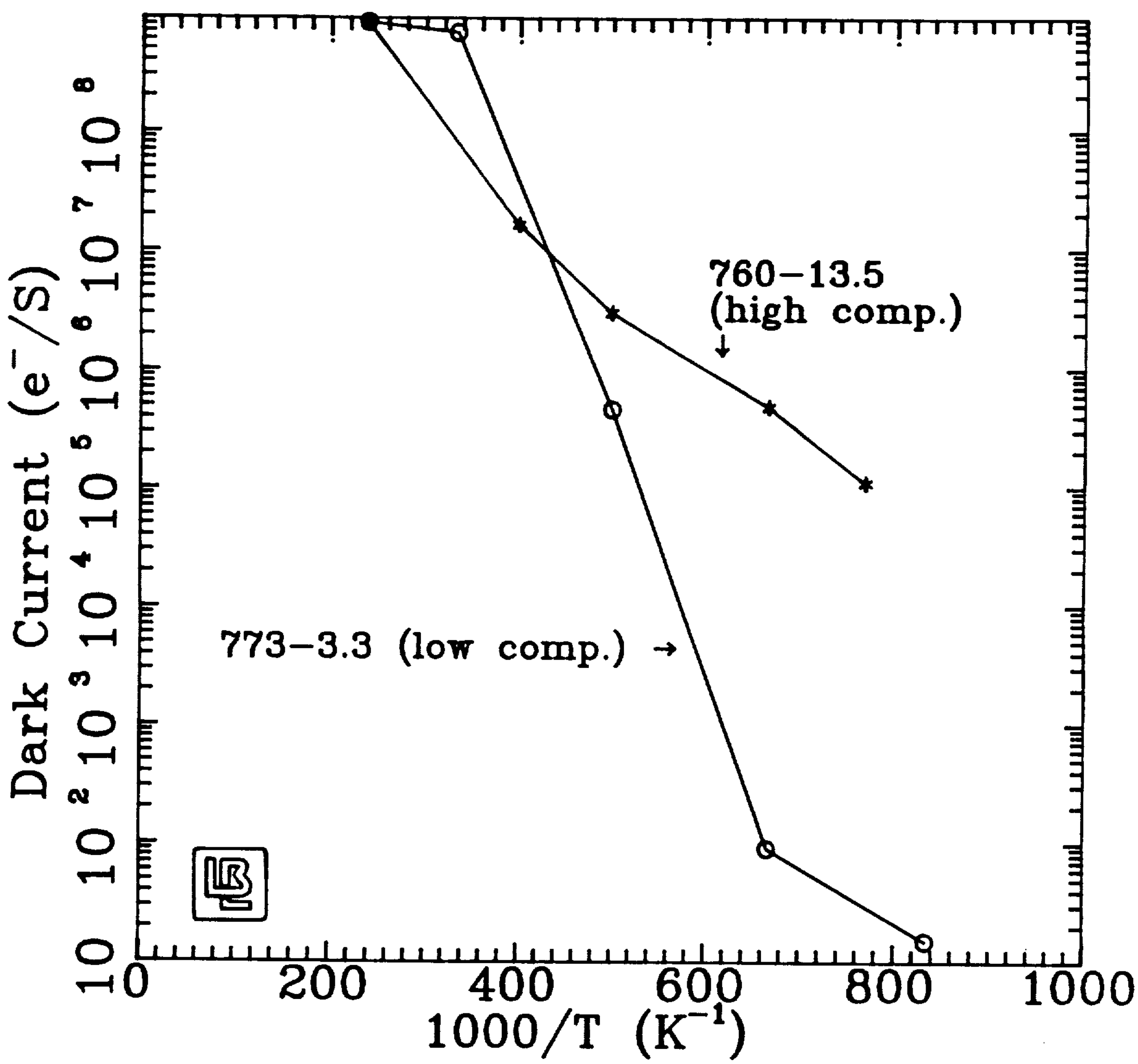
- higher compensation material has more hole traps which reduces carrier lifetime, and should, in turn, lead to devices with lower dark current
  this is not observed

- detectors exhibiting low dark currents were made from boules with a low occurrence of crystalline imperfections (dislocations)

- we have grown a series of dislocation-free materials to further study this correlation



Hall effect of two Ge:Ga samples.
The 760 material is much more highly compensated than the 773 material



Freeze−out of two stressed detectors. Unlike unstressed Ge:Ga, high compensation does not necessarily reduce dark current.

BEHAVIOR OF LOW DARK CURRENT STRESSED Ge:Ga

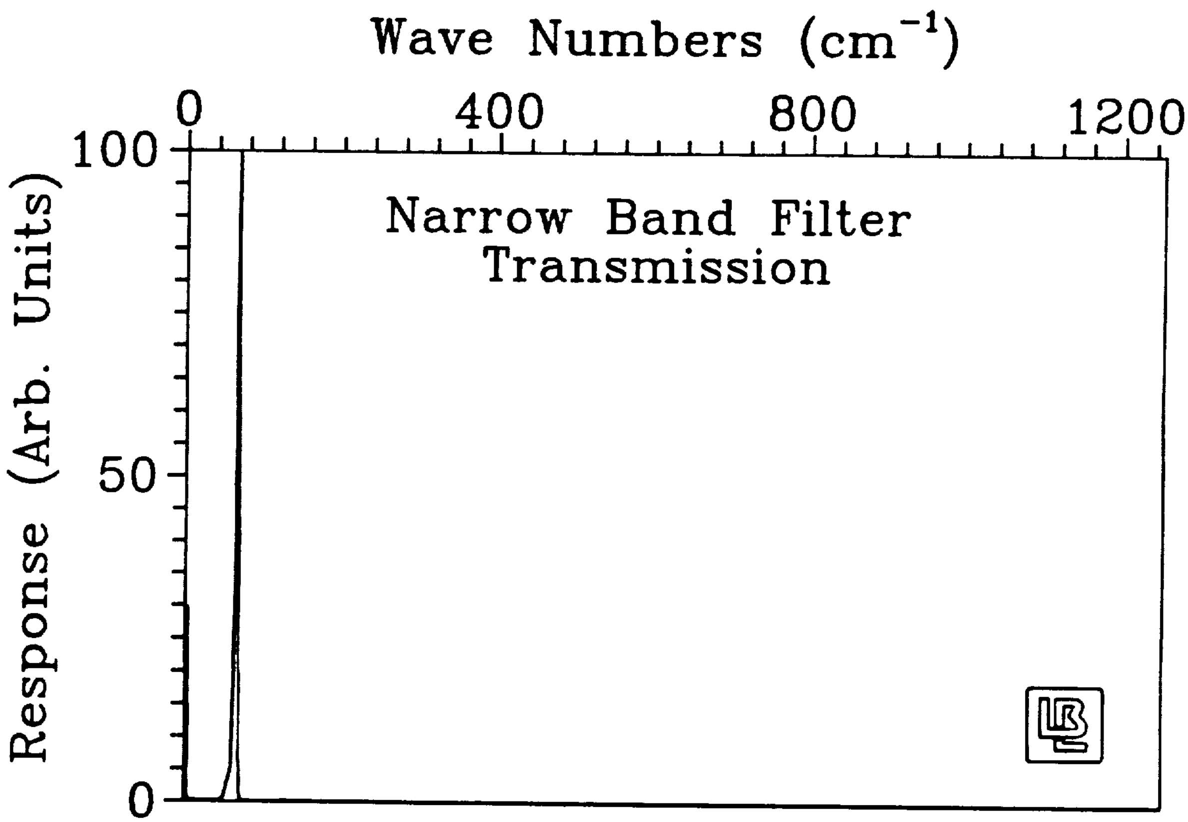
- dislocation-free device 773-3.3 shows favorable responsivity and NEP when tested with transimpedance amplifiers

- detective quantum efficiency is approximately 9%

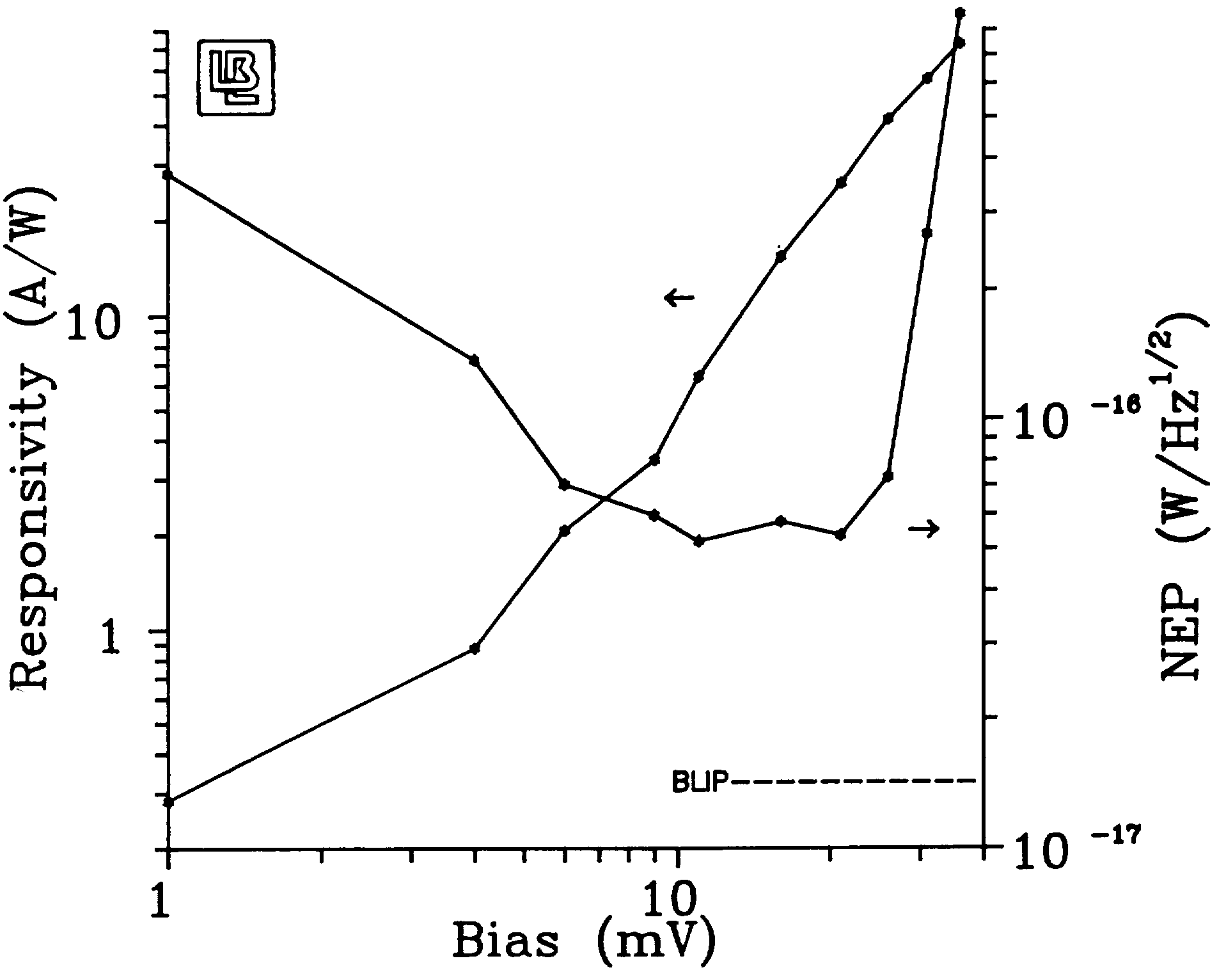
- should be able to reach background-limited performance with integrating amplifiers

- low operating bias voltage: breakdown field is approximately 50 mV/mm

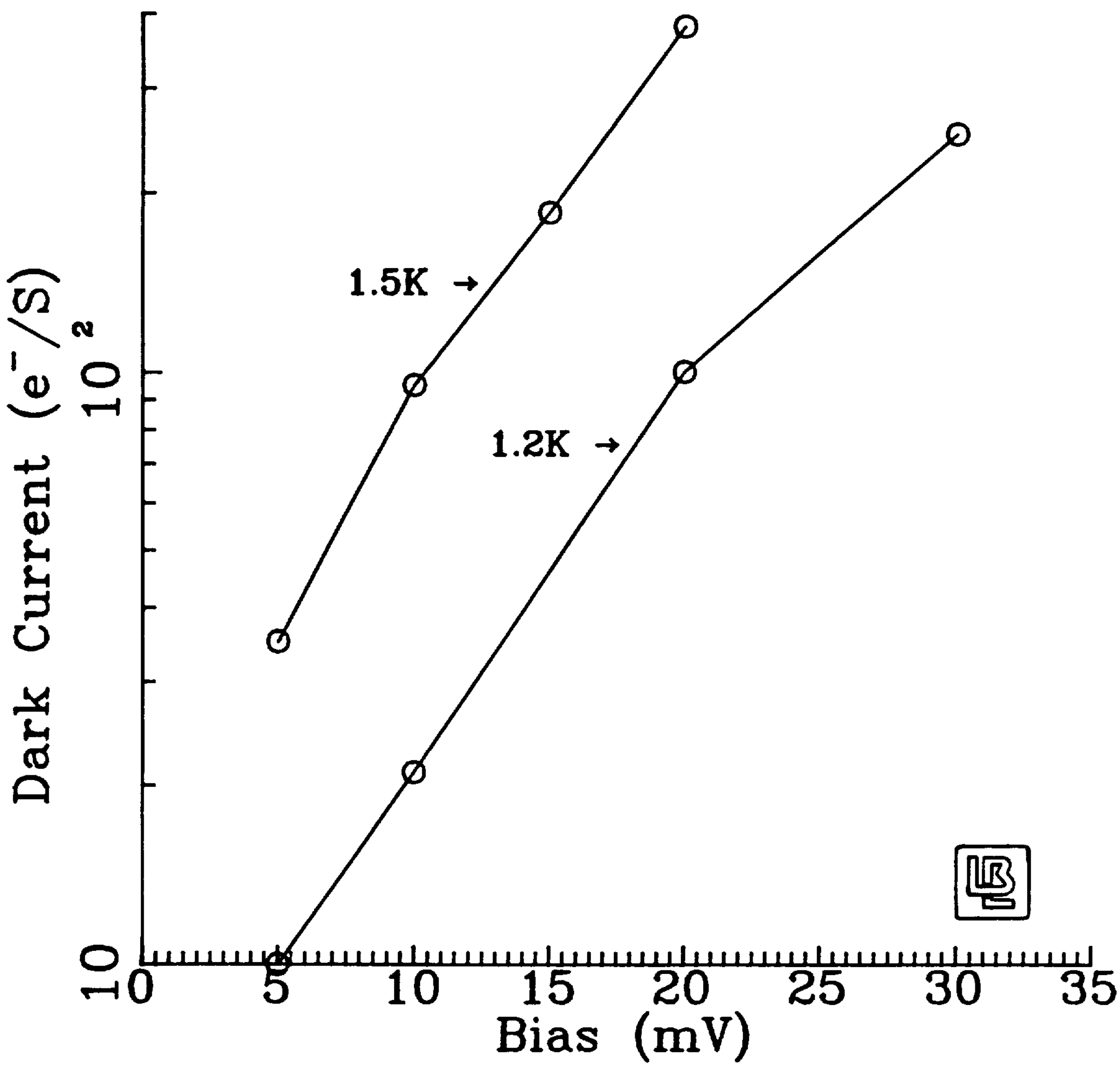
- dark current is a strong function of bias



- 163 μm Peak Transmission
- 5.84×10^{-14} W Peak to Peak Signal
  (4.81×10^{7} Photons/Sec.)
- 2.66×10^{-14} W RMS Signal



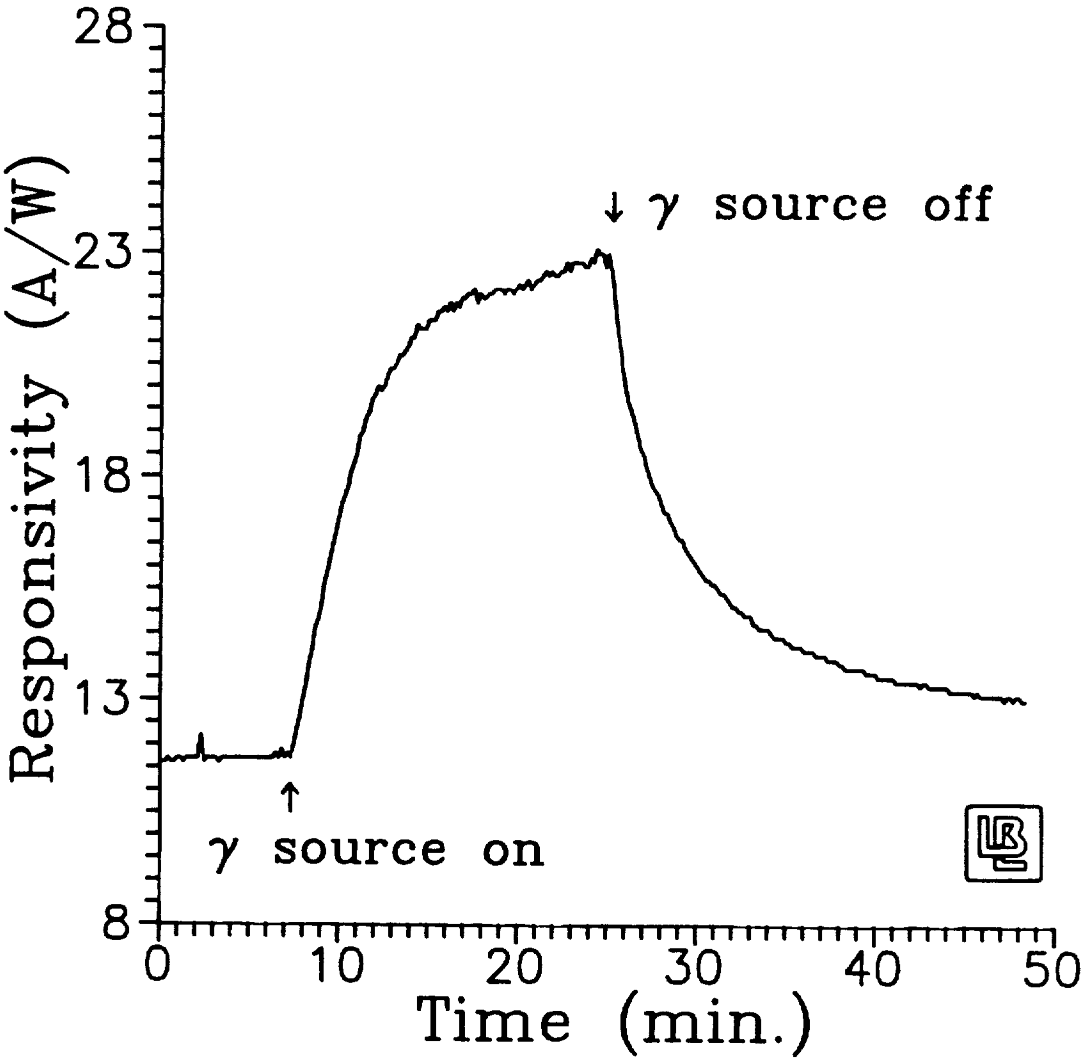
Responsivity and NEP of 773−3.3, dislocation−free Ge:Ga stressed detector. Conditions = TIA mode, $f_{chopper}$ = 23 Hz, 1.3K, stressed to 40% of room temperature resistance.



Dark current vs Bias for stressed Ge:Ga 773–3.3. Conditions = 0.5 X 1 X 1 mm chip, (1 mm interelectrode distance), results are the average of two independant tests.

PROBLEMS

- "cold" operation (1.5K or less) is required
- array construction is more complicated than with unstressed detectors
- low bias voltage may result in greater frequency of integrating amp resets
- ionizing radiation effects are similar to other photoconductor materials



Effect of ionizing radiation on stressed Ge:Ga 773–3.3 (approx. 40 counts/sec. 60 KV γ)

CONCLUSIONS

- detectors exist today for background-limited detection at 200 microns

- we are "narrowing in" on the significant parameters that effect dark current in stressed photoconductors. These findings may apply to other photoconductor materials

- need some "creative problem solving" for an ionizing radiation effect reset mechanism