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Stressed Ge:Ga Photoconductors for Space–Based Astronomy

(Is There Life Beyond 120 μm?)

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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

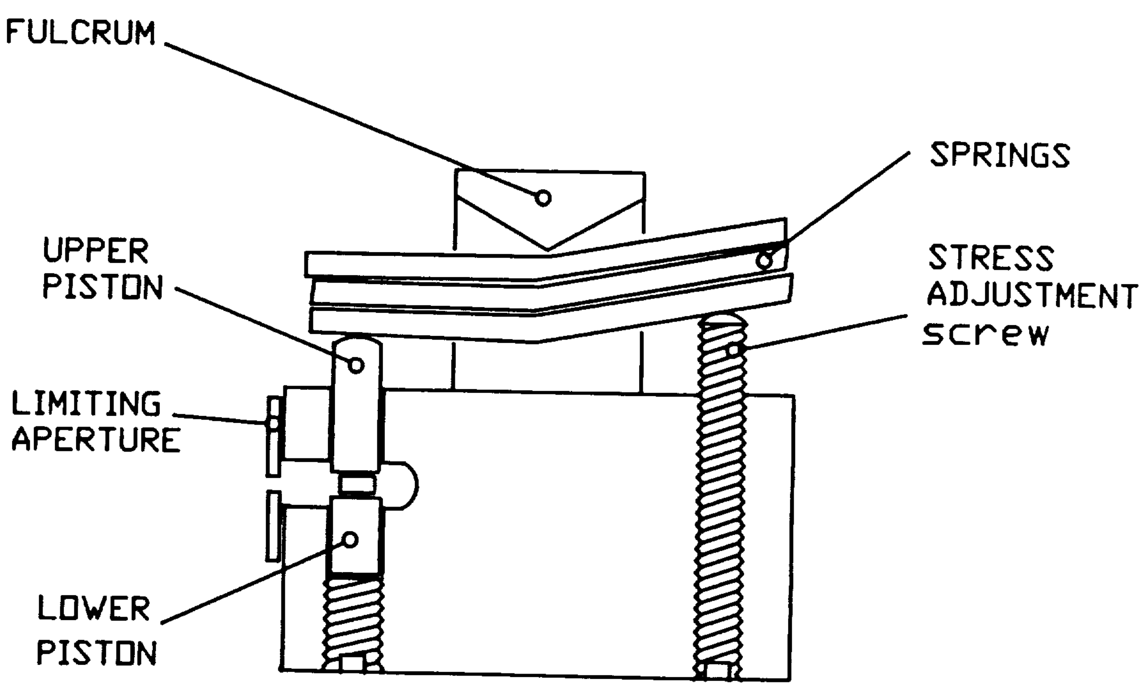
STRESSED Ge:Ga

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

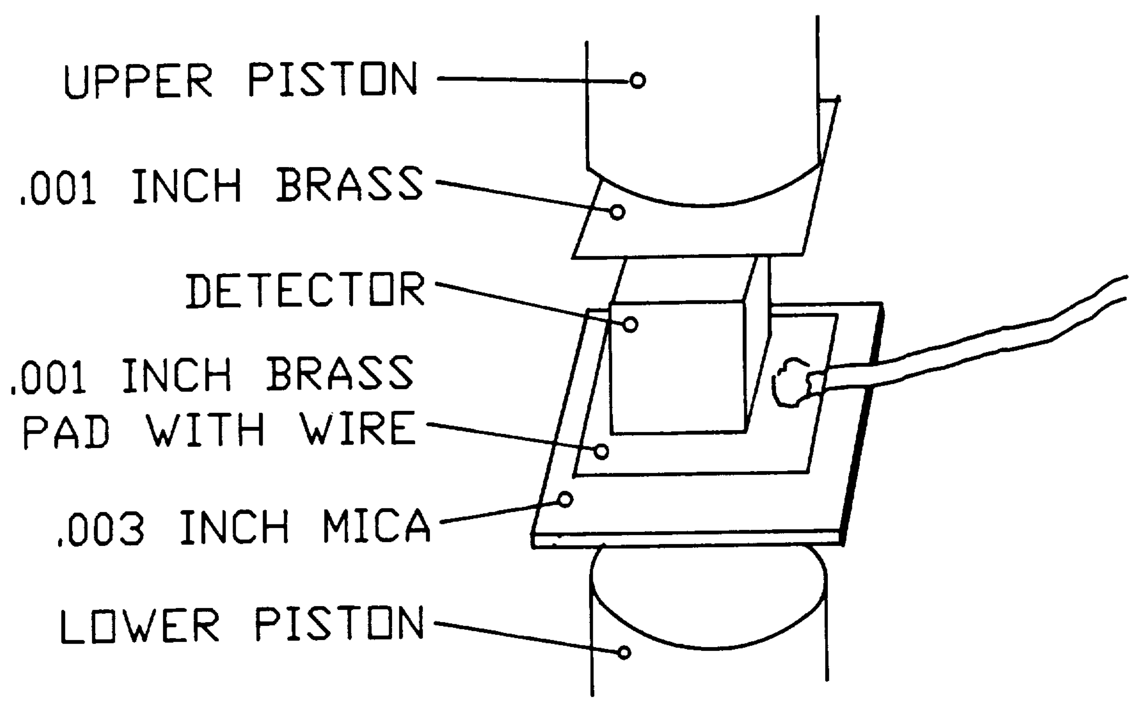
- reduces binding energy of holes

- 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

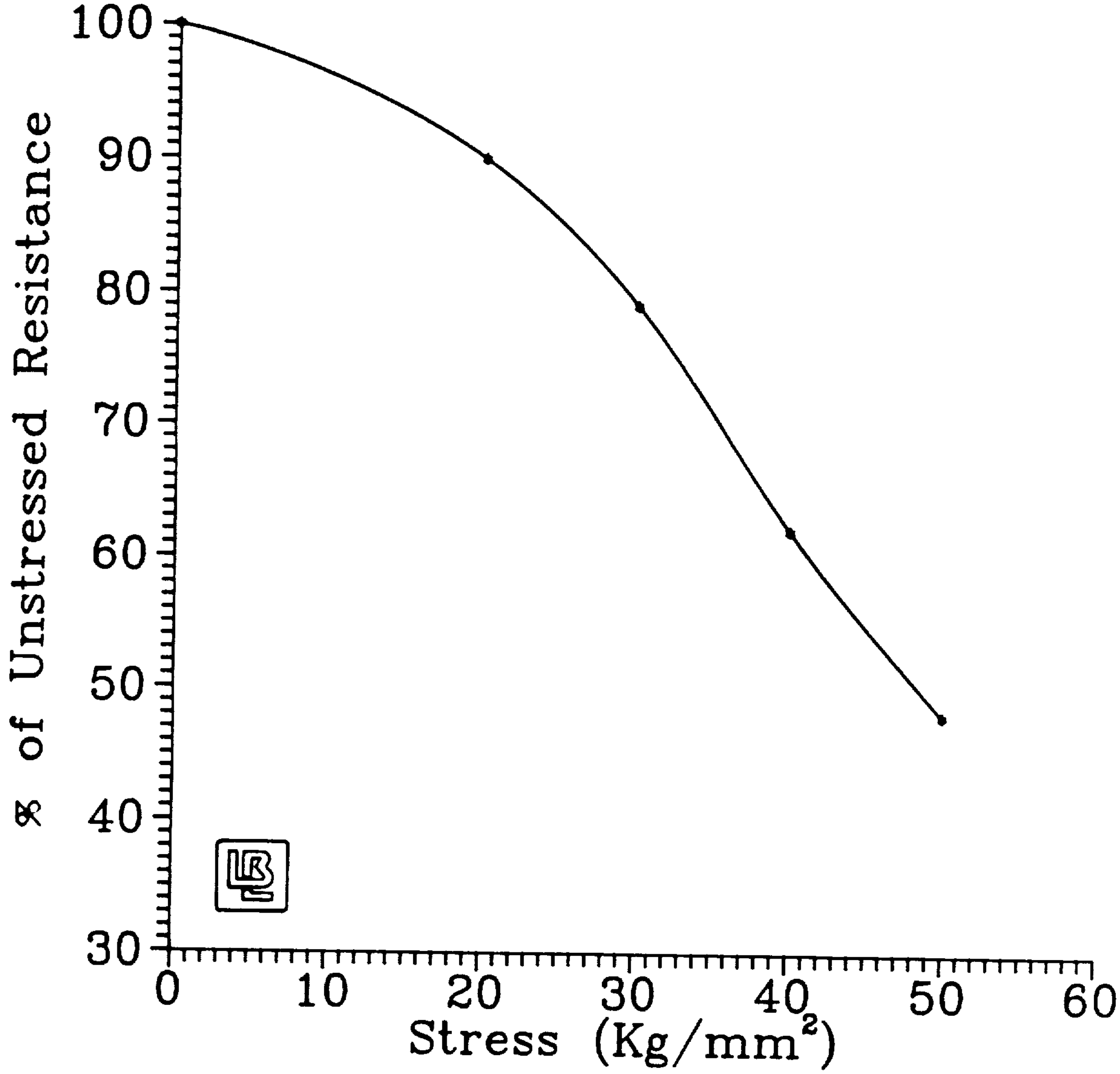
    * highly planar: keeps stress on-axis

AMOUNT OF STRESS

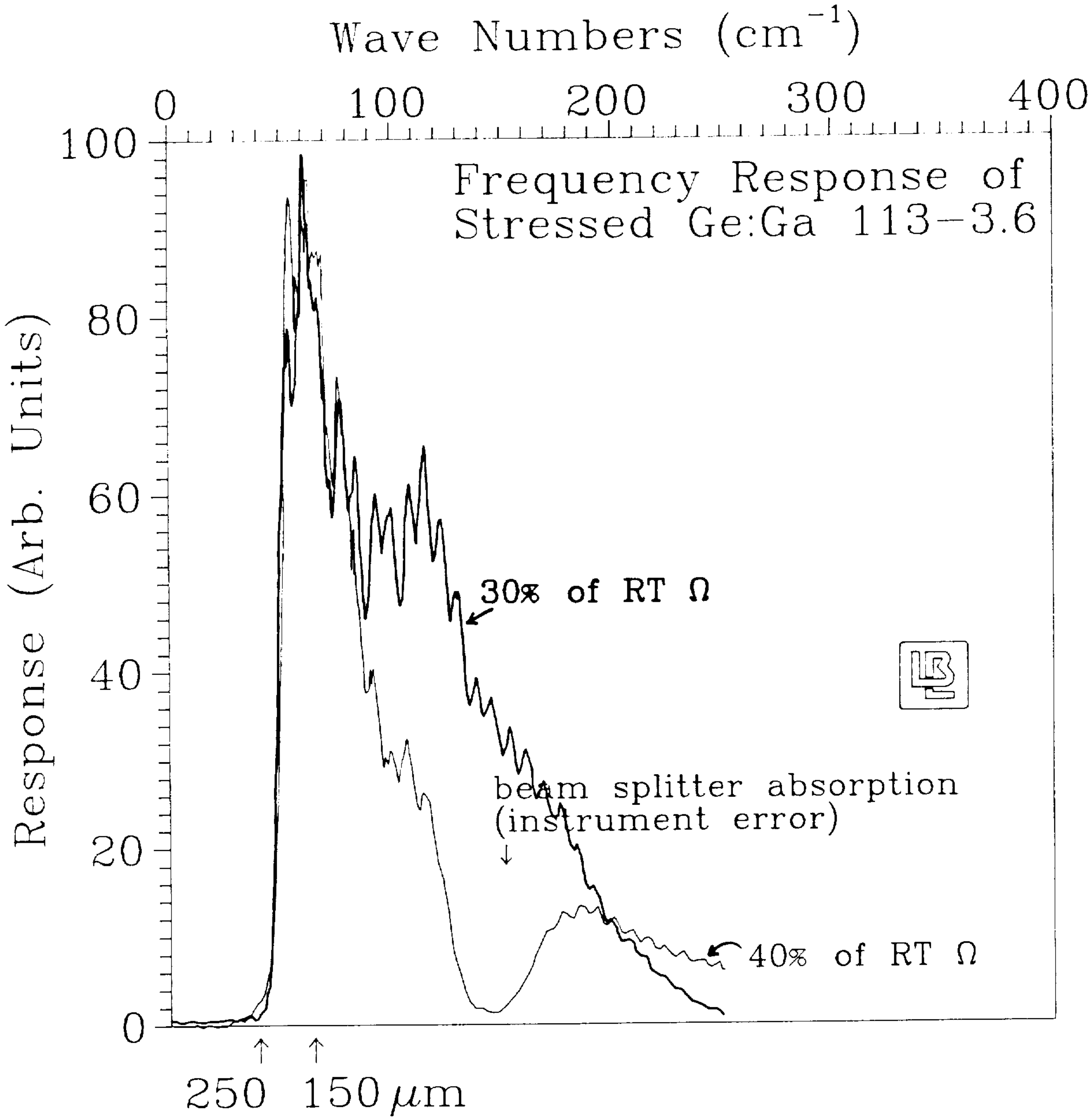
- the mobility of carriers increases with stress, therefore we need only monitor the detector's room temperature resistance to measure the applied stress

- 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)



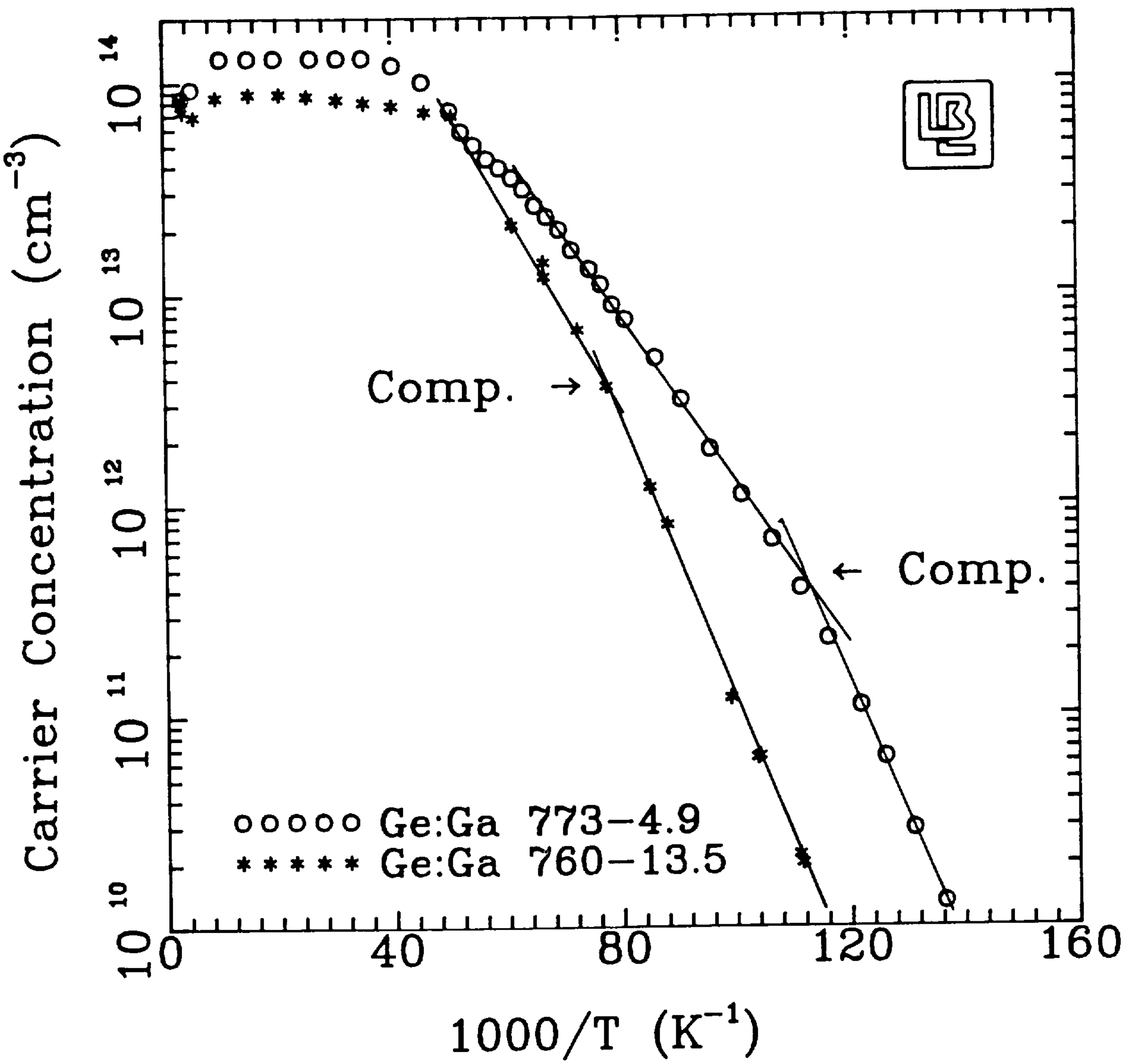
Detector response as a function of wavelength. Long wavelength extension saturates at 40% RT Ω. Additional stress (30% curve) does not further extend long wavelength response.

MATERIALS PARAMETERS AFFECTING DARK CURRENT

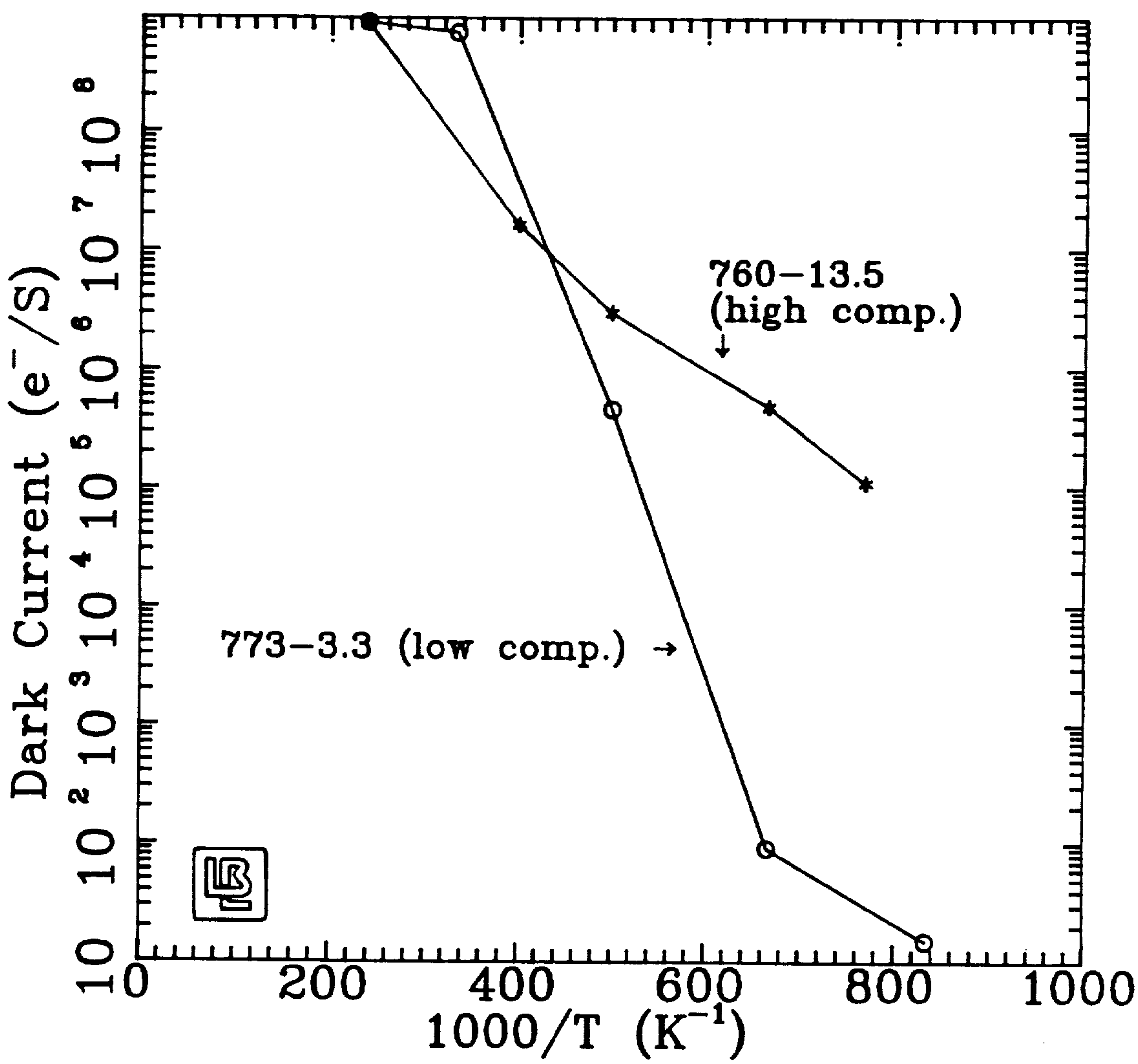
- higher compensation material has more hole traps which reduces carrier lifetime, and should, in turn, lead to devices with lower dark current
  <u>this is not observed</u>

- 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

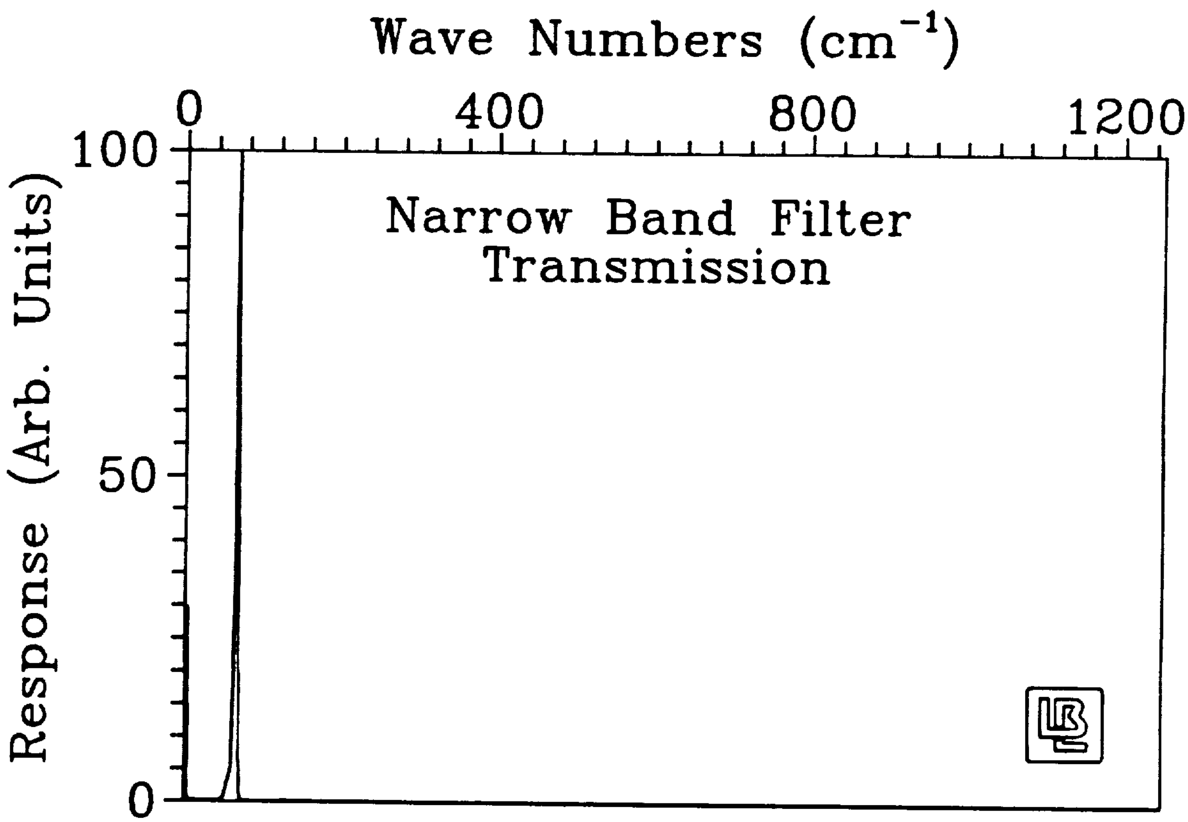
- dislocation-free device 773-3.3 shows favorable responsivity and NEP when tested with transimpedance amplifiers

- detective quantum efficiency is approximately 9%

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

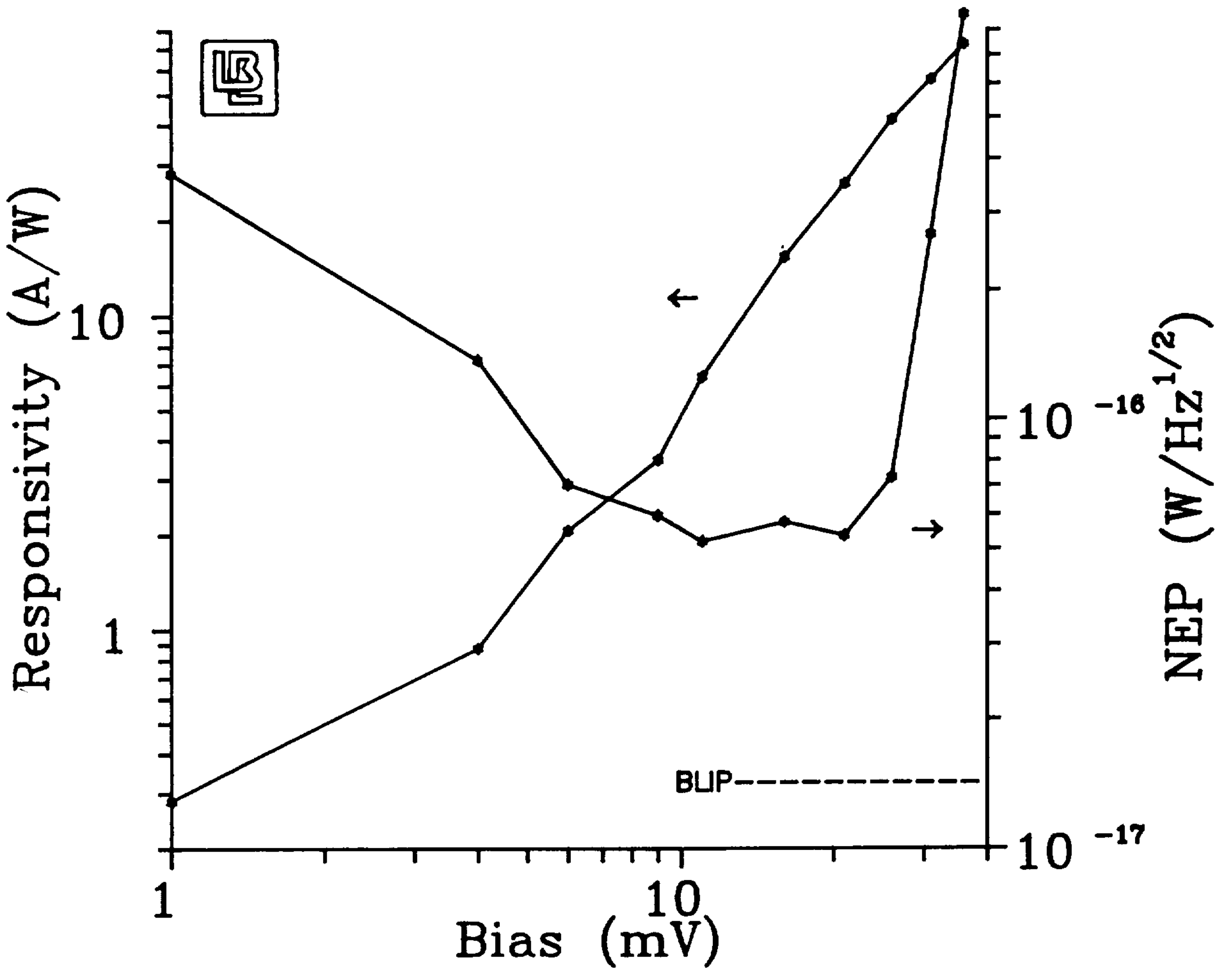
- low operating bias voltage: breakdown field is approximately 50 mV/mm

- dark current is a strong function of bias

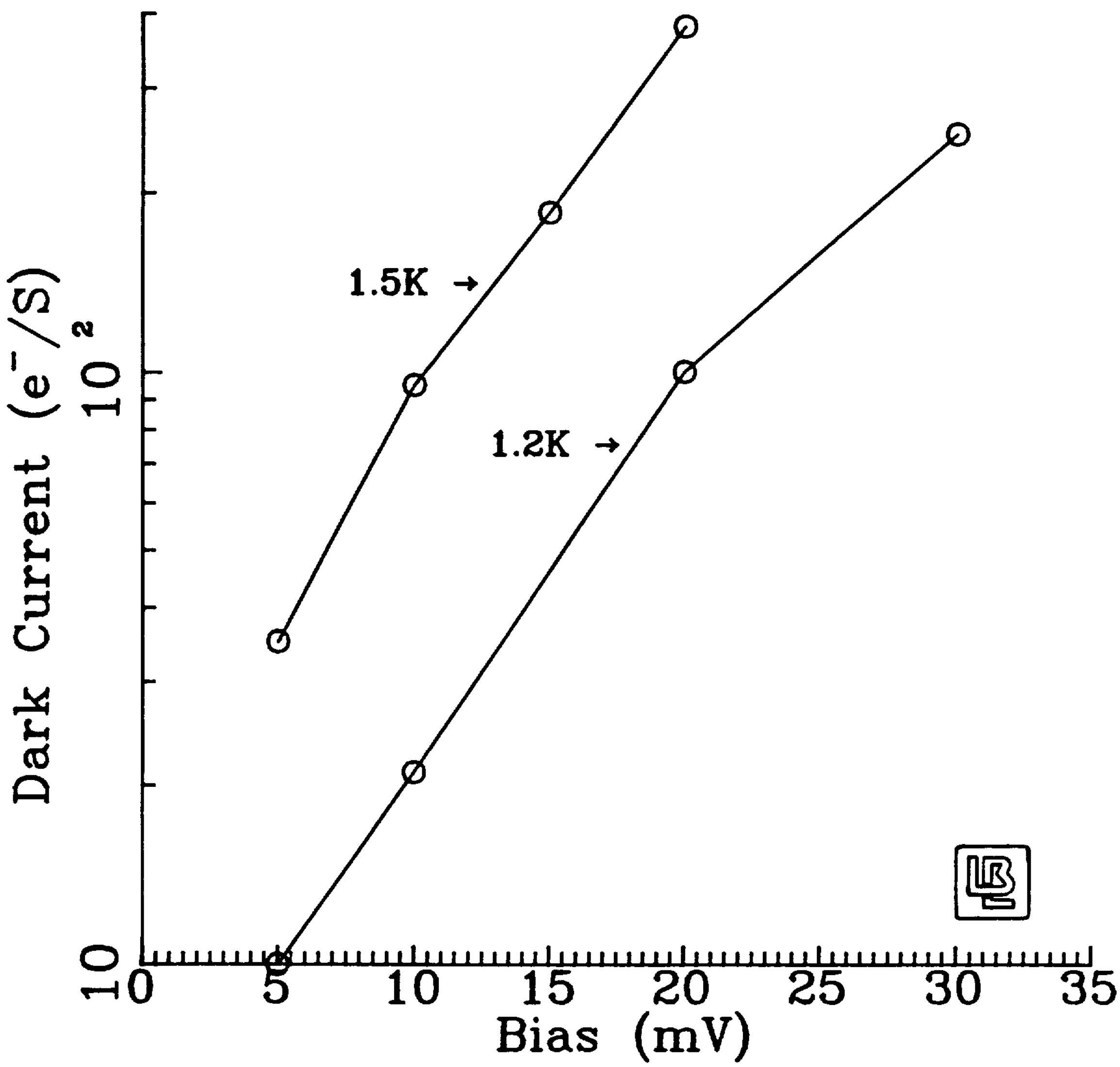


- 163 μm Peak Transmission
- 5.84×10^{-14} W Peak to Peak Signal

  (4.81×10^{7} Photons/Sec.)
- 2.66×10^{-14} W RMS Signal



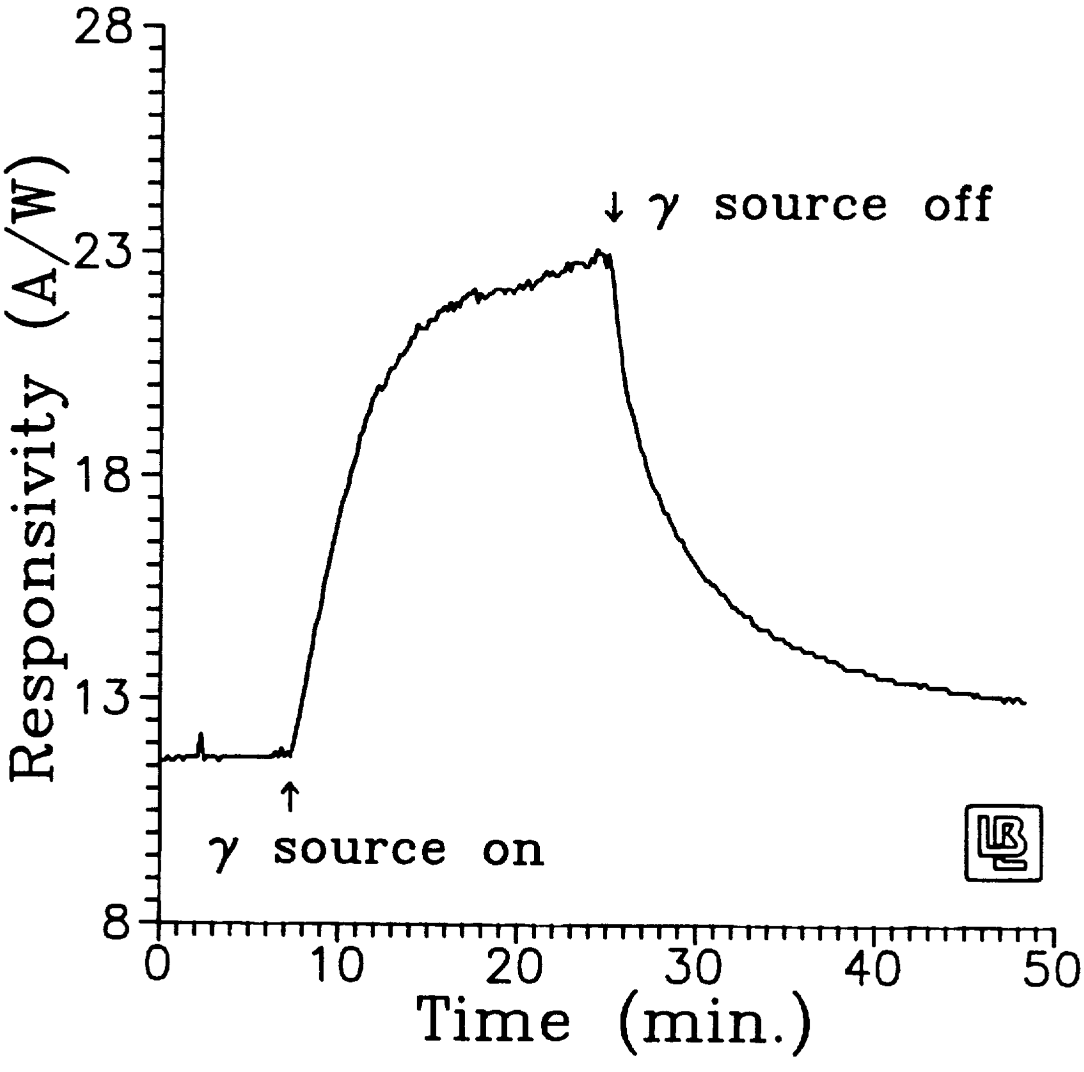
Responsivity and NEP of 773−3.3, dislocation−free Ge:Ga stressed detector. Conditions = TIA mode, $f_{chopper}$ = 23 Hz, 1.3K, stressed to 40% of room temperature resistance.



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