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Effects of a p-n Junction on Heterojunction Far Infrared Detectors

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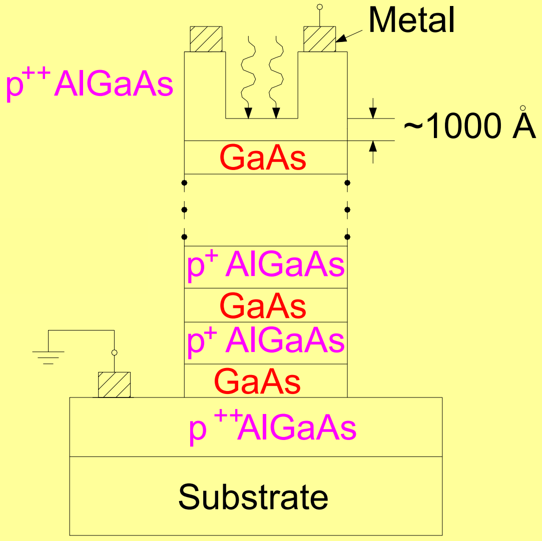
Outline

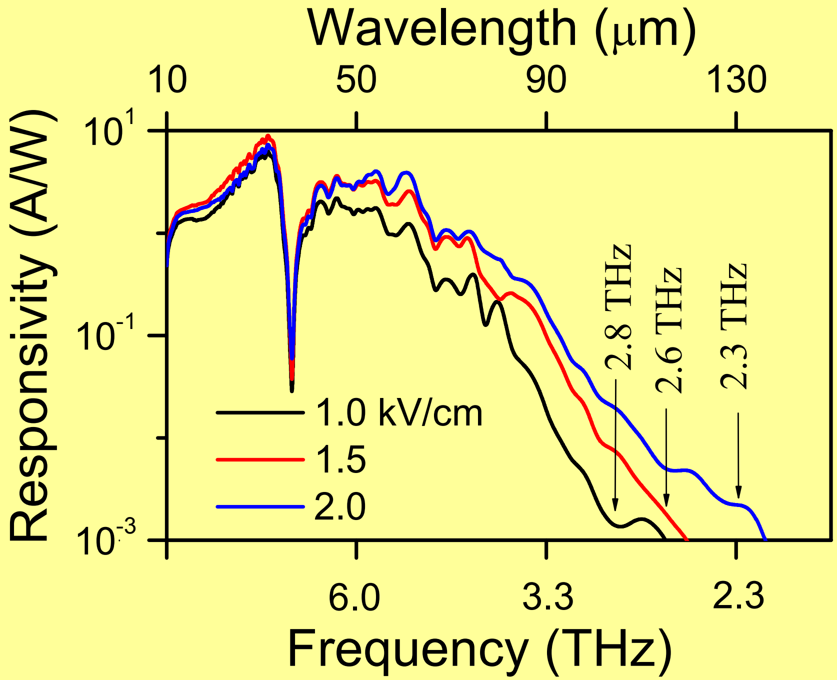
- Introduction
- Other detectors using p-n junctions
- FIR detector results with p-n junctions
- Modeling results
- Conclusions

HEIWIP Detectors

f_0 : 2.3 THz Al Fraction 0.005 AlGaAs Emitters



After processing

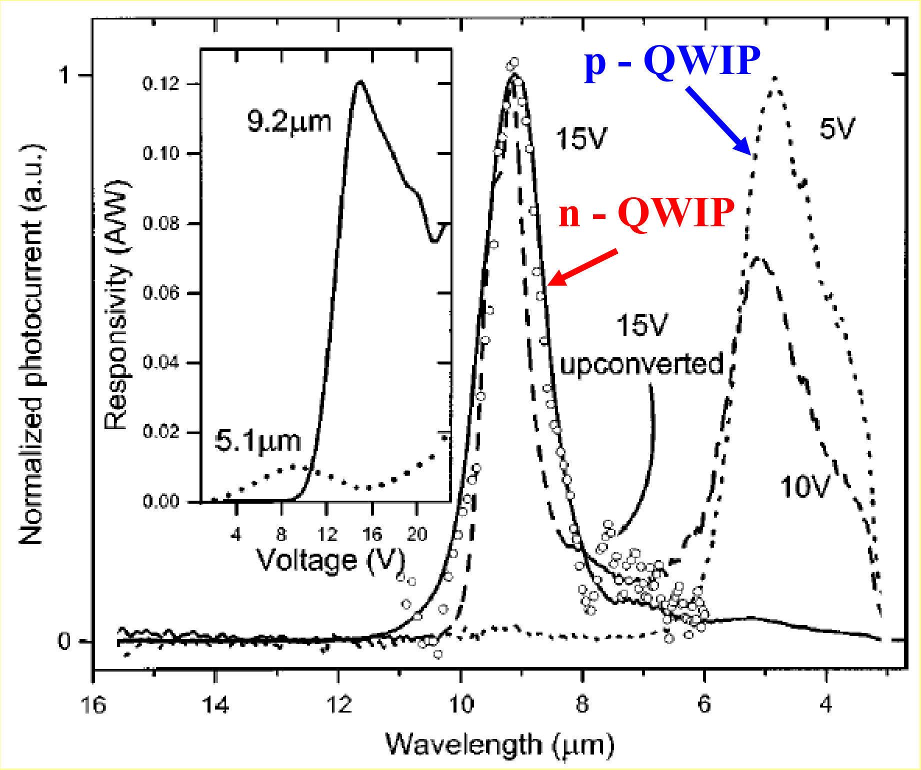


M. B. M. Rinzan, A. G. U. Perera, S. G. Matsik, H. C. Liu, Z. R. Wasilewski, and M. Buchanan, APL **86**, 071112 (2005)

p- and n-QWIP combinations

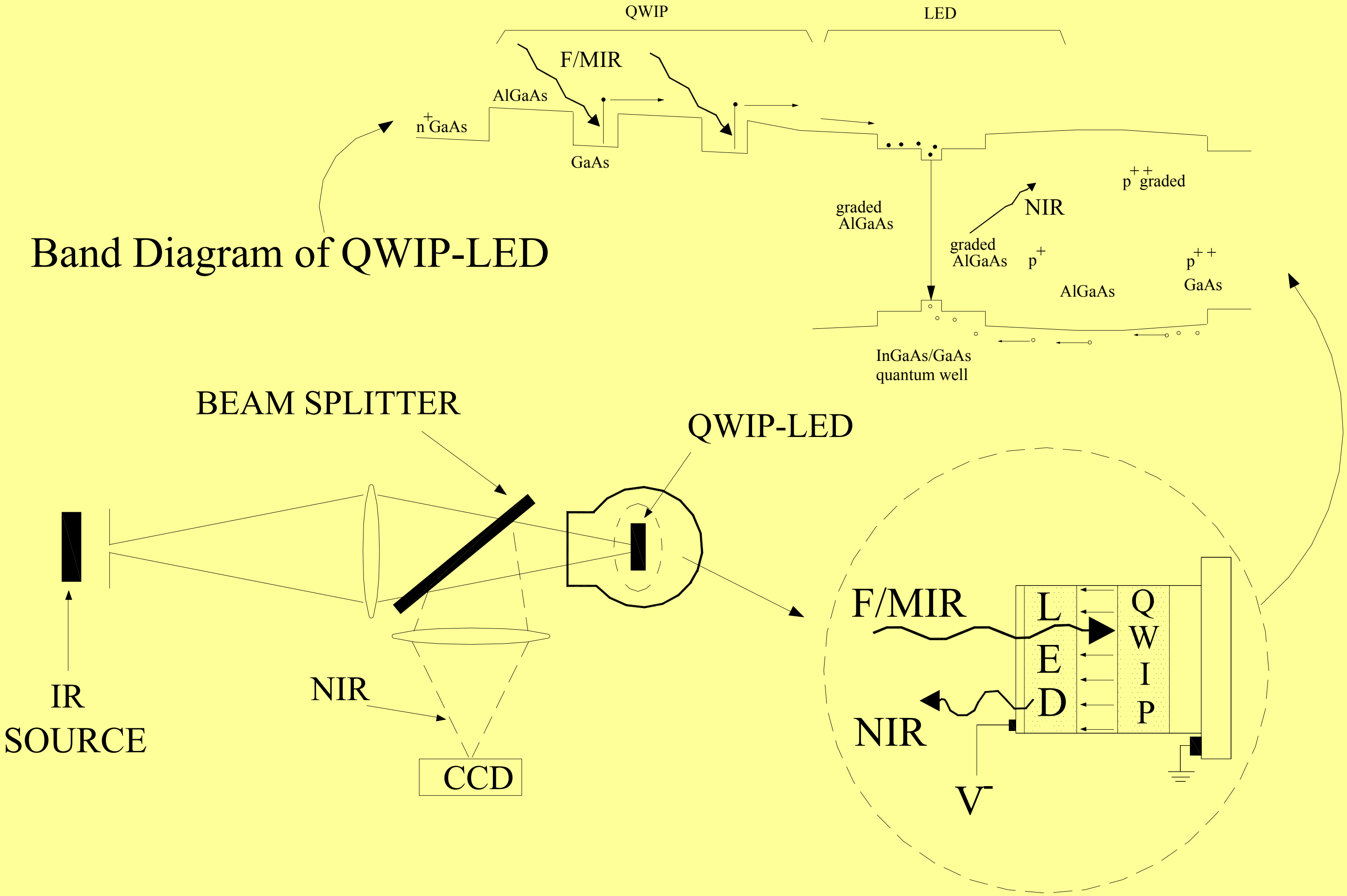
150 Å p^{++} GaAs (Be) = 2 X1 0^{19} cm^{-3}	
600 Å p^{++} Al$_{0.07}$Ga$_{0.93}$As (Be) = 2 X1 0^{19} cm^{-3}	
2000 Å p^{+} AlGaAs (Al) = 55 % to 7% (Be) = 1 0^{19} cm^{-3}	
31 Å GaAs / 250 Å Al$_{0.55}$Ga$_{0.45}$As 40 periods (Be) = 4 X1 0^{12} cm^{-2}	p-QWIP 5 µm band
800 Å AlGaAs graded up (Al): 10% to 55%	
300 Å i-GaAs	QW-LED
400 Å AlGaAs graded down (Al): 24% to 10%	
54 Å GaAs / 400 Å Al$_{0.24}$Ga$_{0.76}$As 50 periods (Si) = 4 X1 0^{11} cm^{-2}	n-QWIP 9 µm band
10000 Å n^{+} GaAs (Si) = 1.5 X1 0^{18} cm^{-3}	
SI GaAs 2" substrate	

80 K



E. Dupont, M. Gao, Z. Wasilewski, and H. C. Liu
APL **78**, 2067 (2001)

QWIP-LED

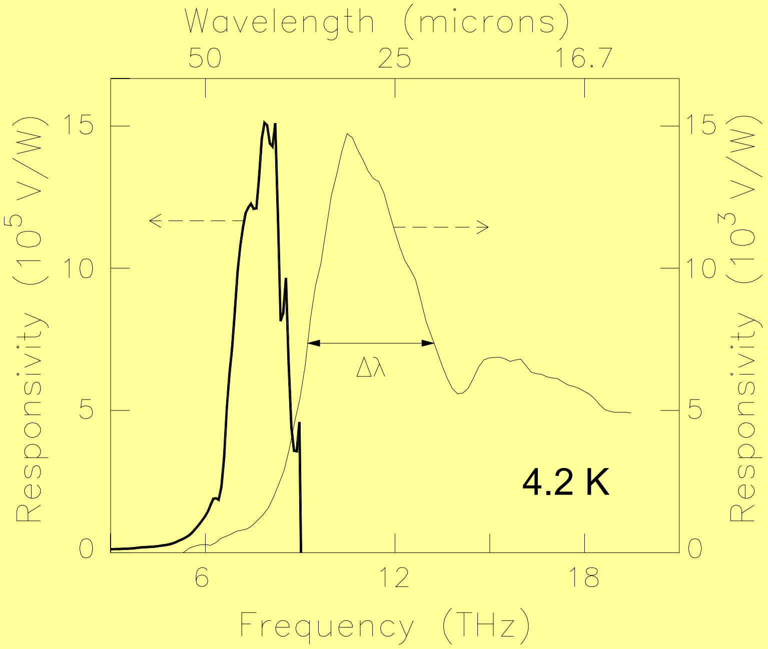


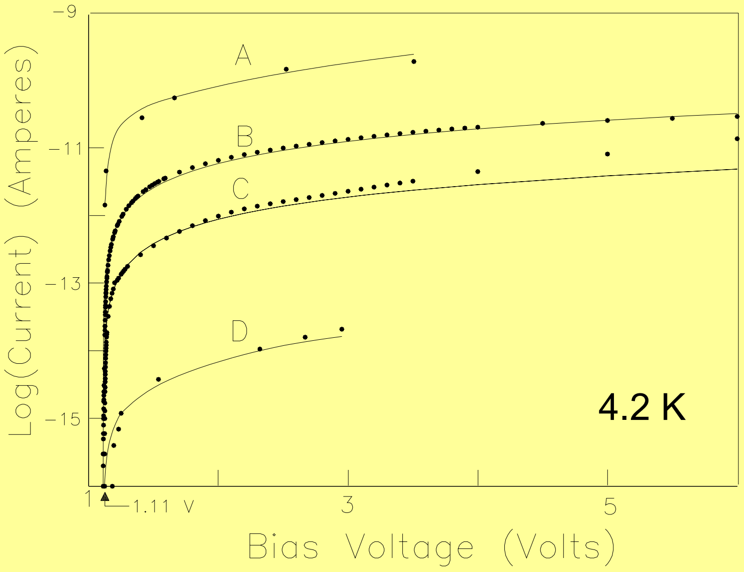
Band Diagram of QWIP-LED

QWIP-LED SETUP

E. Dupont, M. Byloos, M. Gao, M. Buchanan, C. Y. Song, Z. R. Wasilewski, and H. C. Liu, IEEE Photonics Tech. Lett. **14**, 182 (2002)

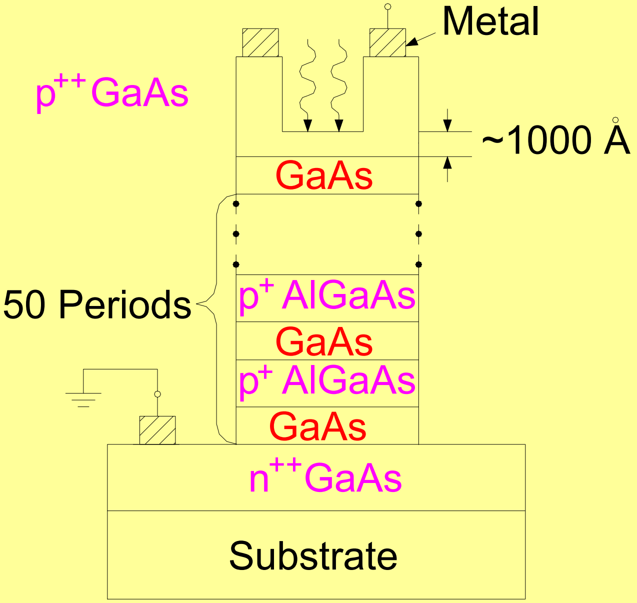
p-i-n Diodes



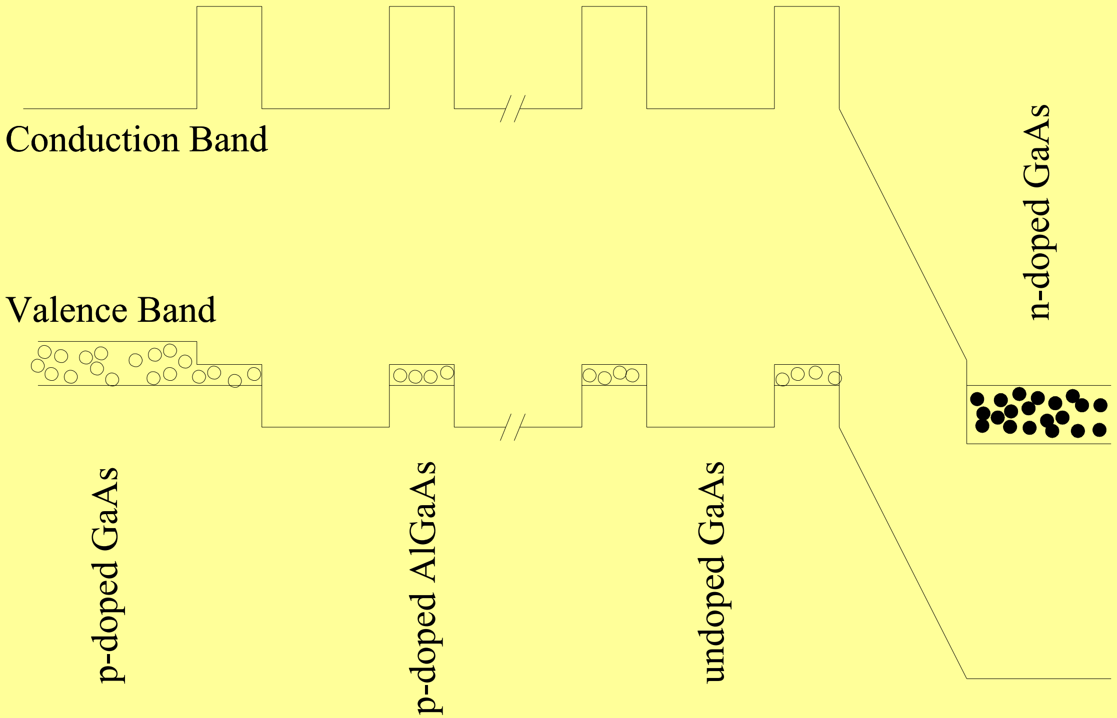


D. D. Coon, R. P. Devaty, A. G. U Perera, and R E Sherriff, APL **55**, 1738 (1989)

FIR Detector with p-n Junction



After processing



50 Periods:

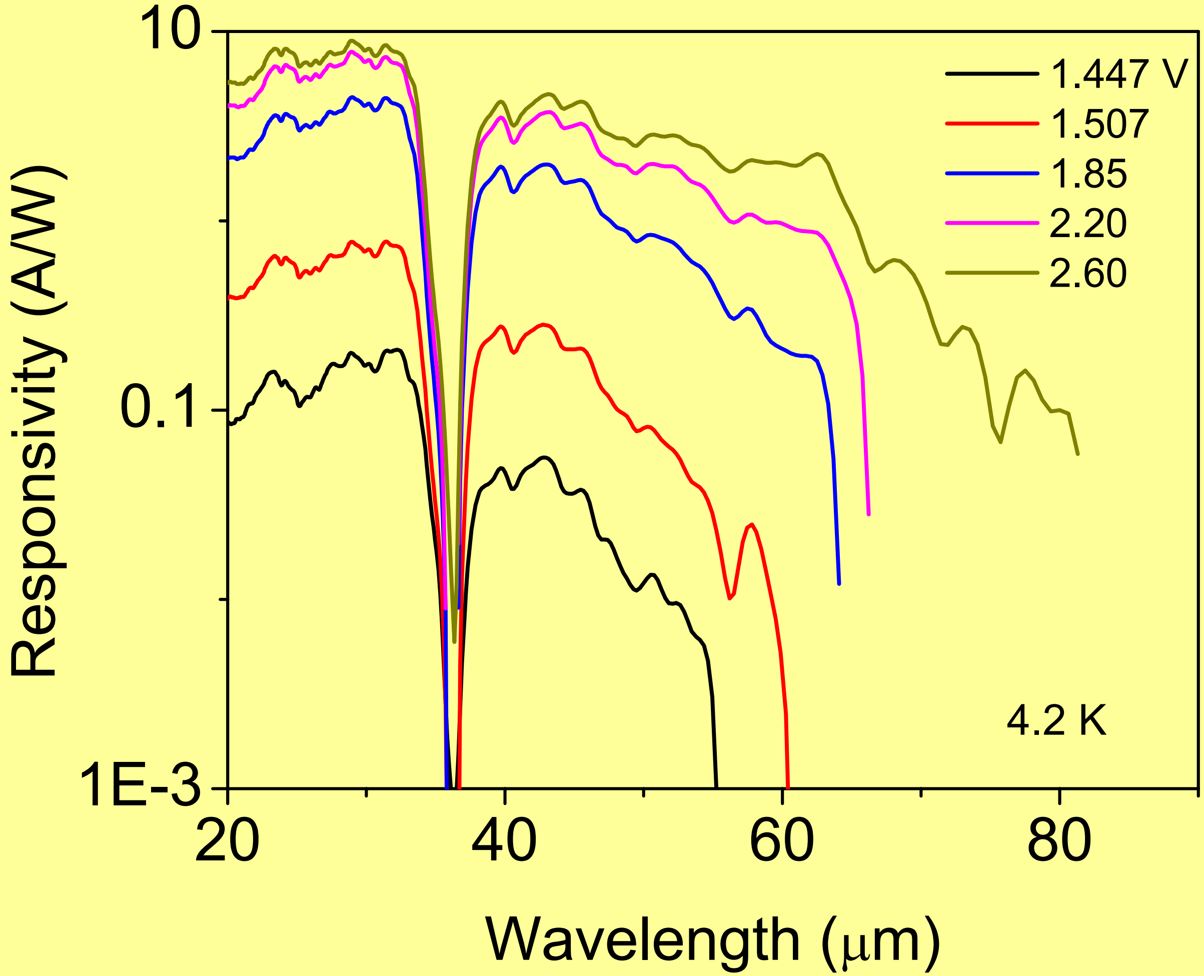
Emitters: 700 Å p-Doped 3×10^{18} cm^{-3} Al$_{0.012}$Ga$_{0.988}$As

Barriers: 2000 Å undoped GaAs

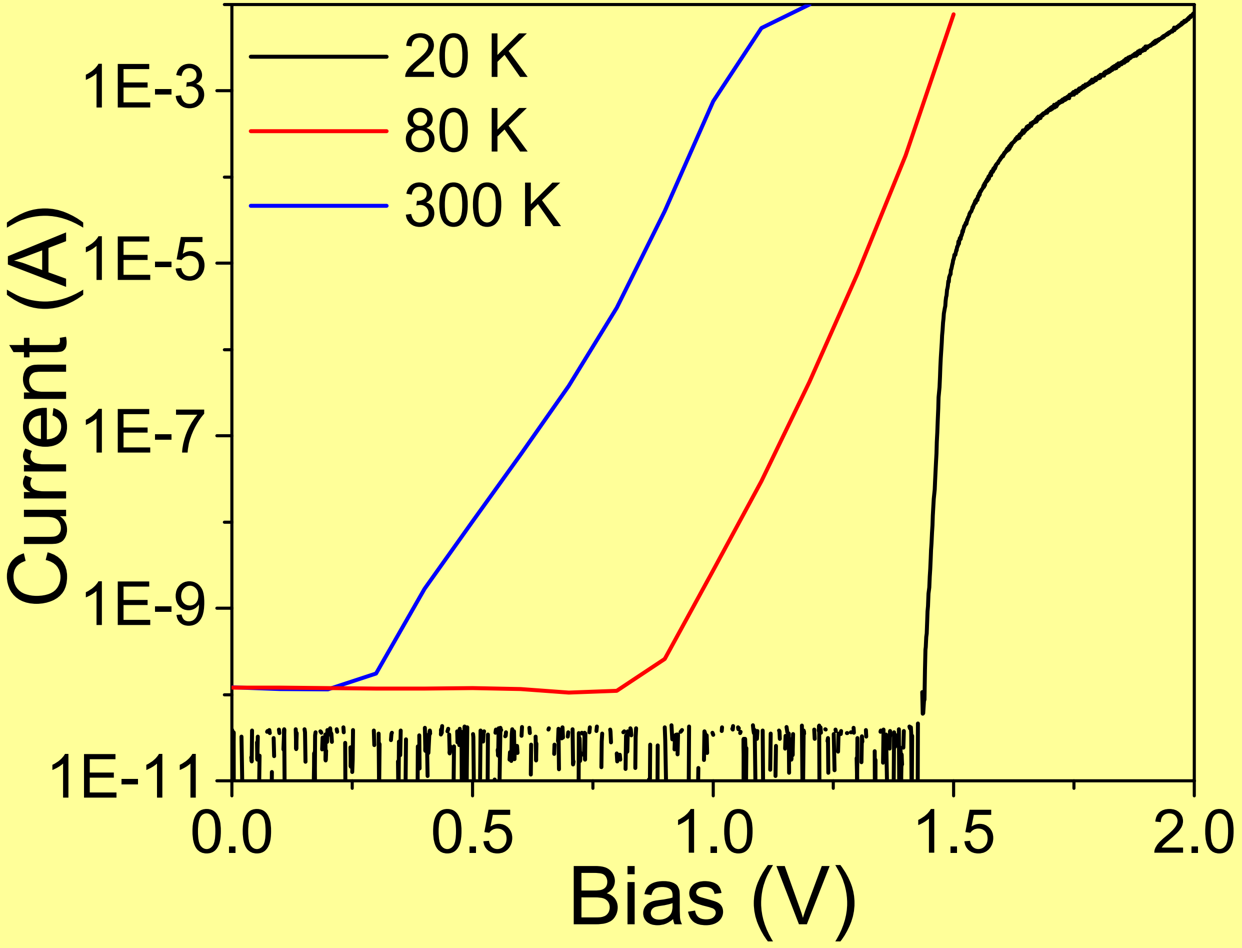
Top Contact: p-Doped 1×10^{19} cm^{-3} GaAs

Bottom Contact: n-Doped 5×10^{18} cm^{-3}

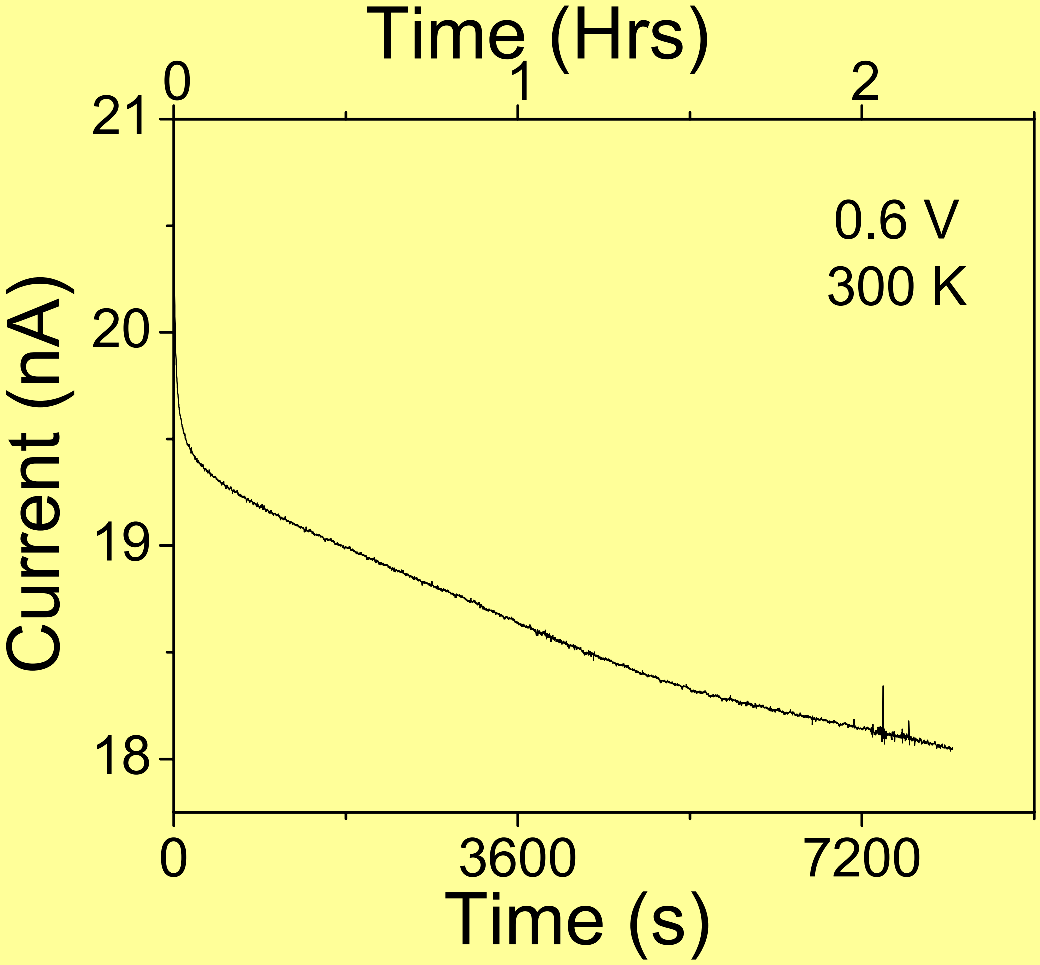
Spectral Response



Threshold voltage vs Temperature

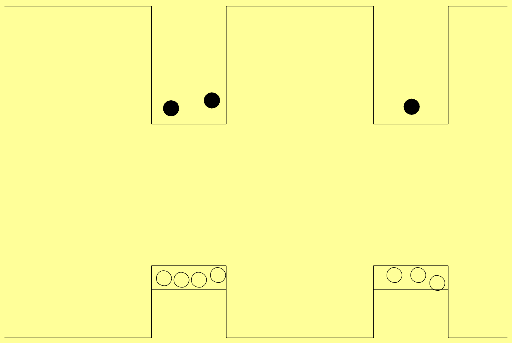


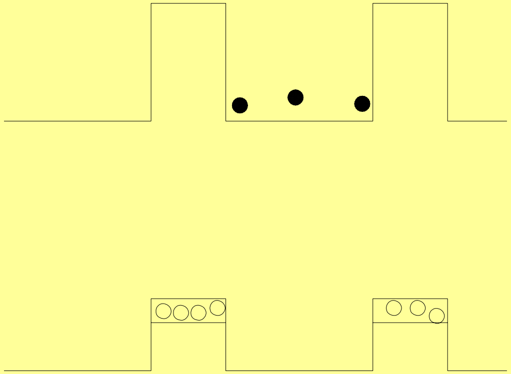
Current vs. Time



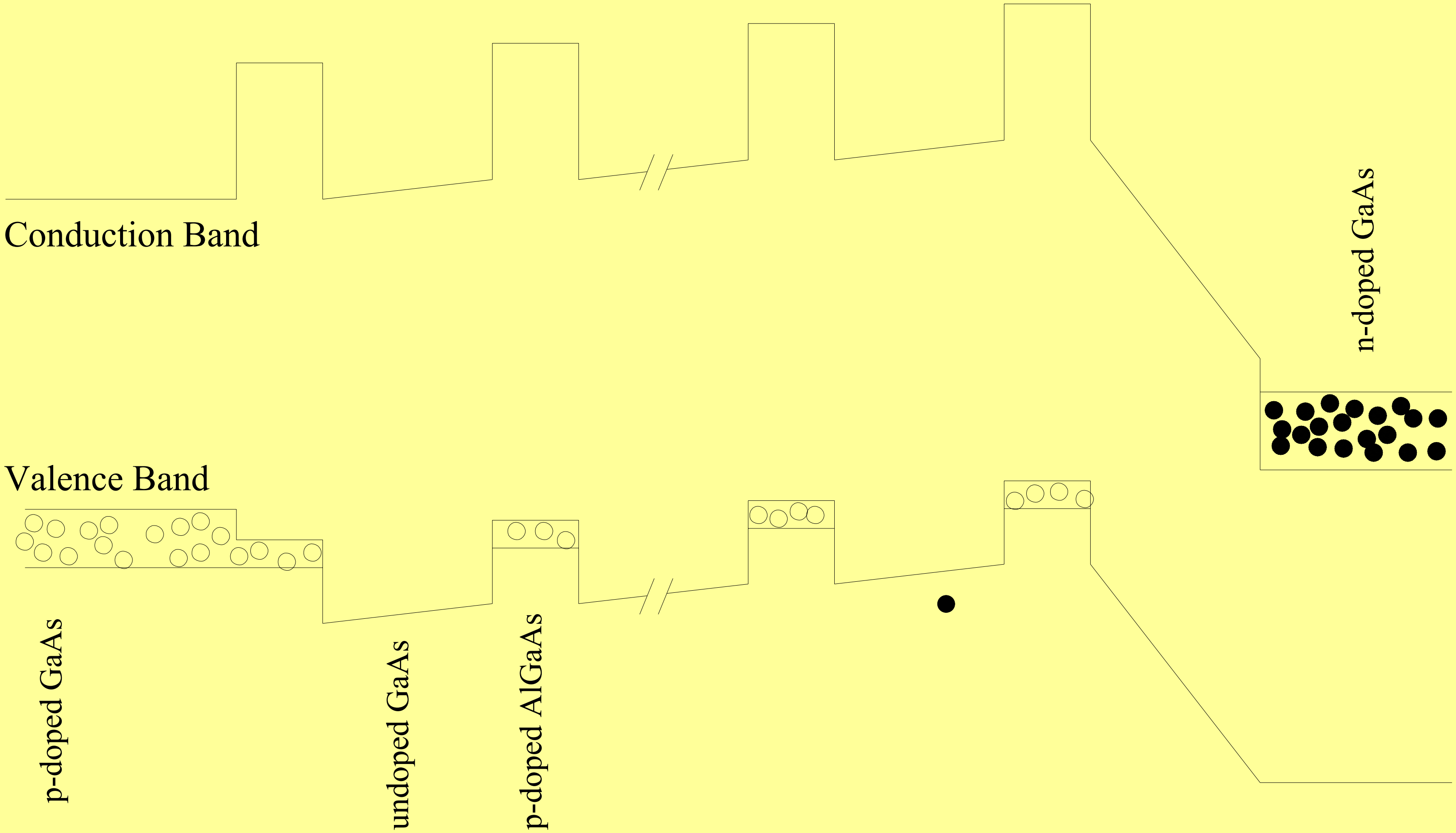
Modeling

- Carrier generation and recombination
  - Dependence on carrier densities
  - Normalization procedure
- Carrier transport
  - Drift-Diffusion
  - Interface effects
  - Tunneling
- Steady state results
- Time dependence results

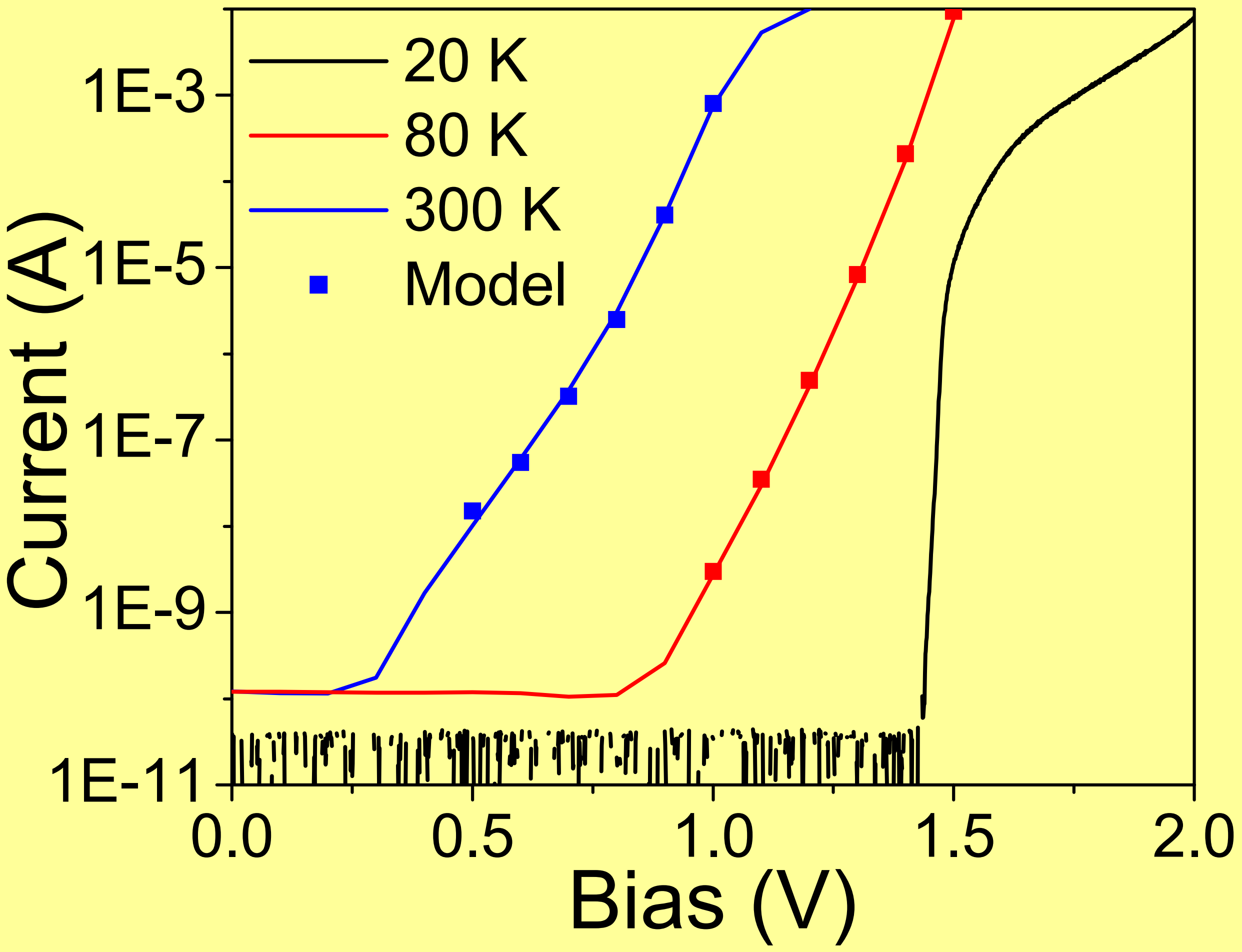

QWIP


HEIWIP (AlGaAs Emitter)

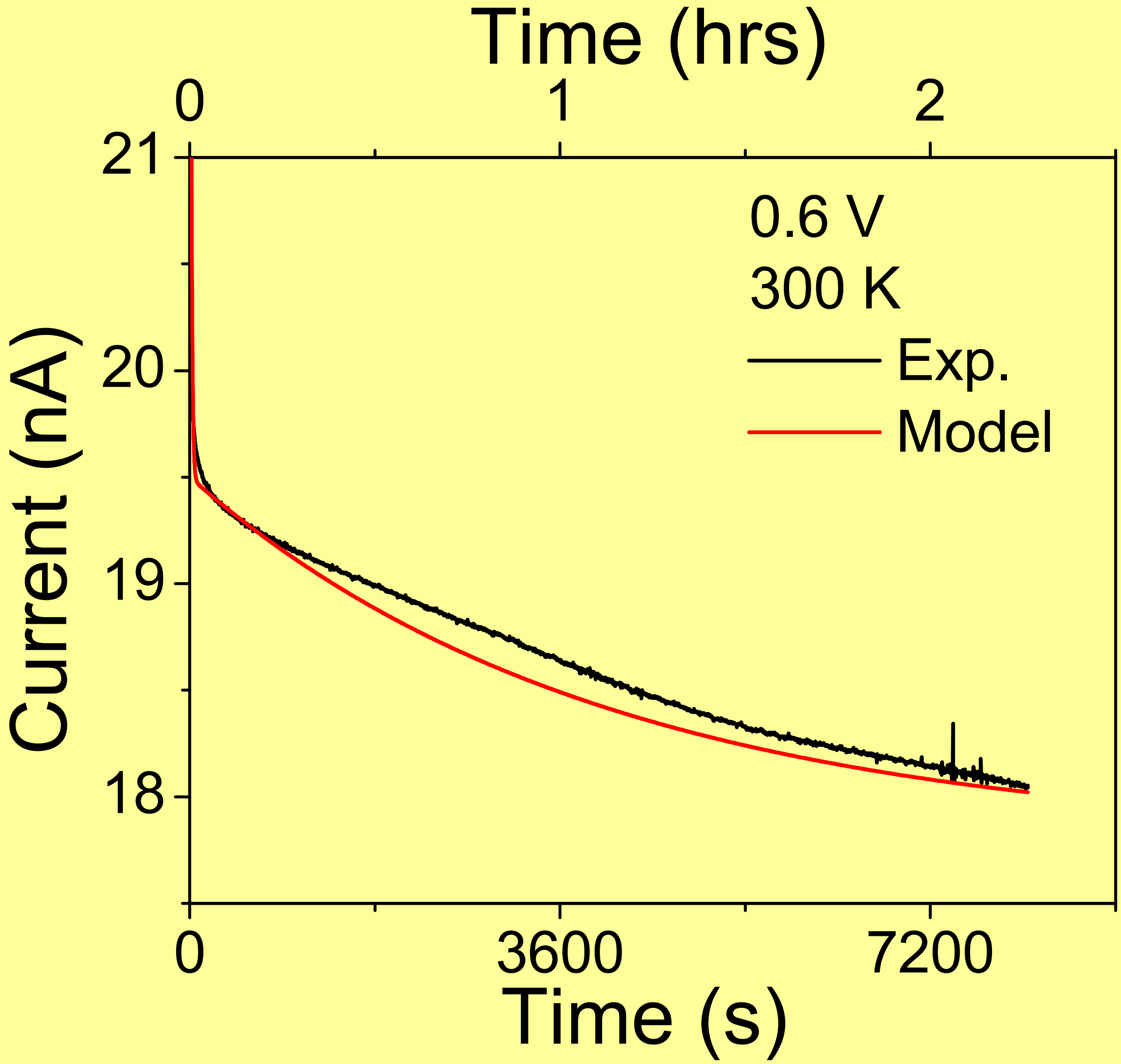
Non-Zero Bias



Steady State Bias Fit

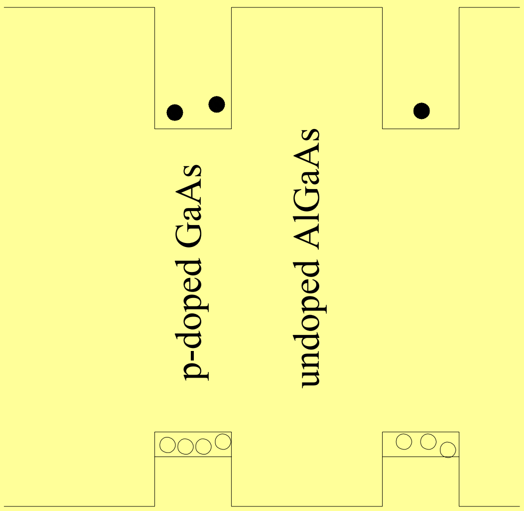


Time Variation Fit

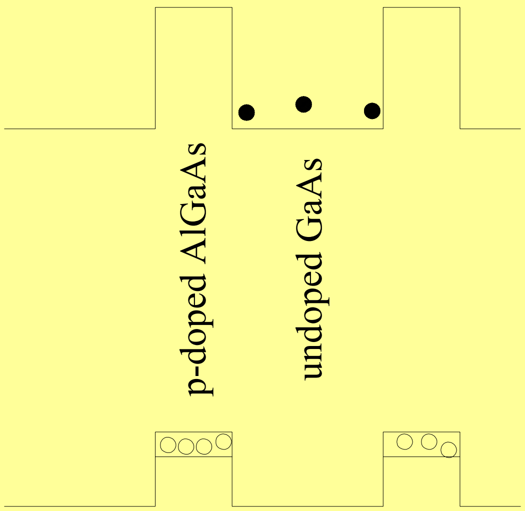


Improvements

Have conduction and valence band wells in the same layer



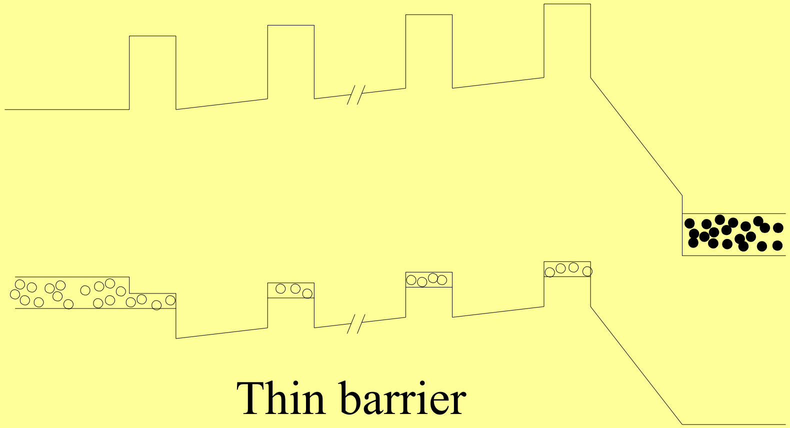
HEIWIP (GaAs emitter)



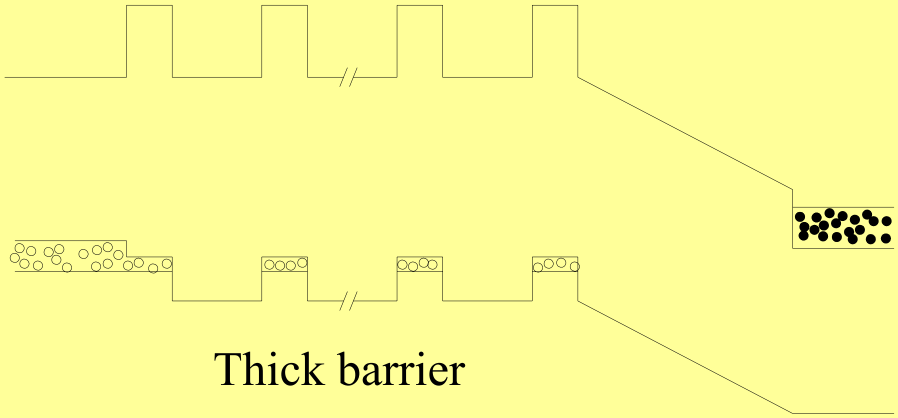
HEIWIP (AlGaAs emitter)

Improvements

Include a thick barrier layer



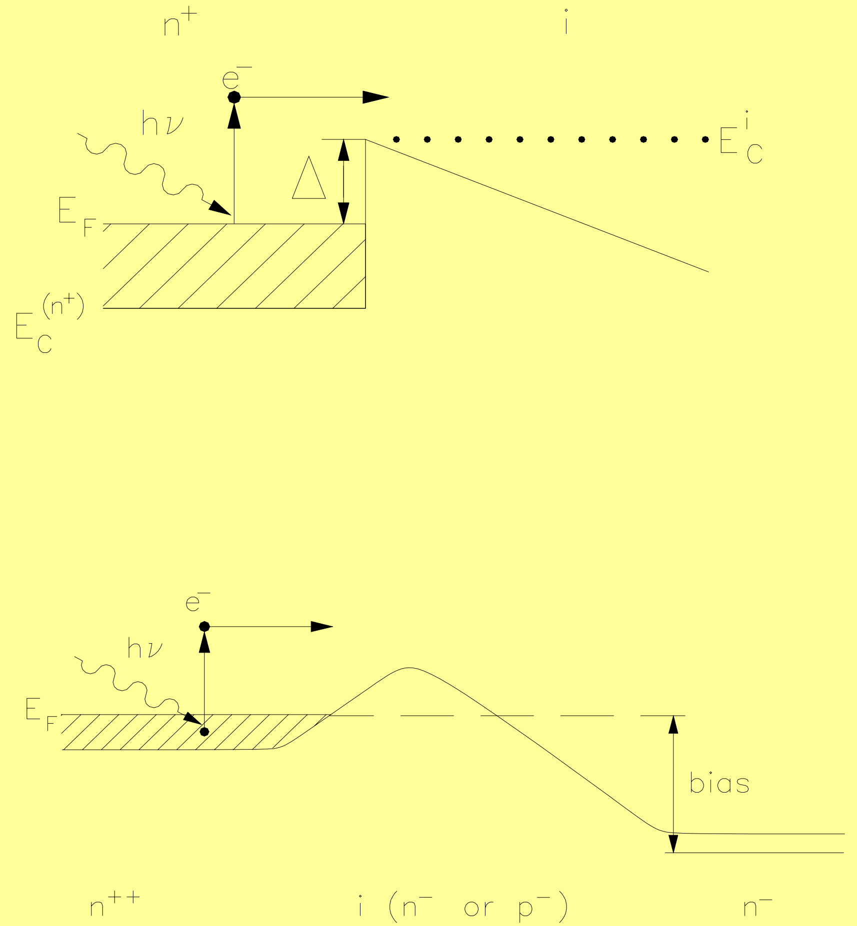
Thin barrier



Thick barrier

Improvements

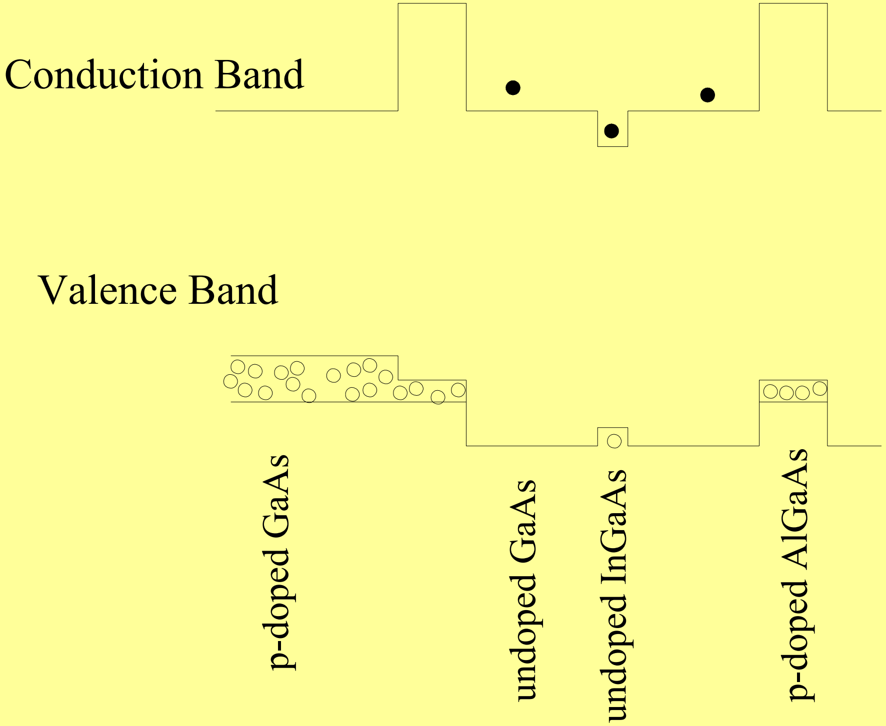
Keep the n-doping low



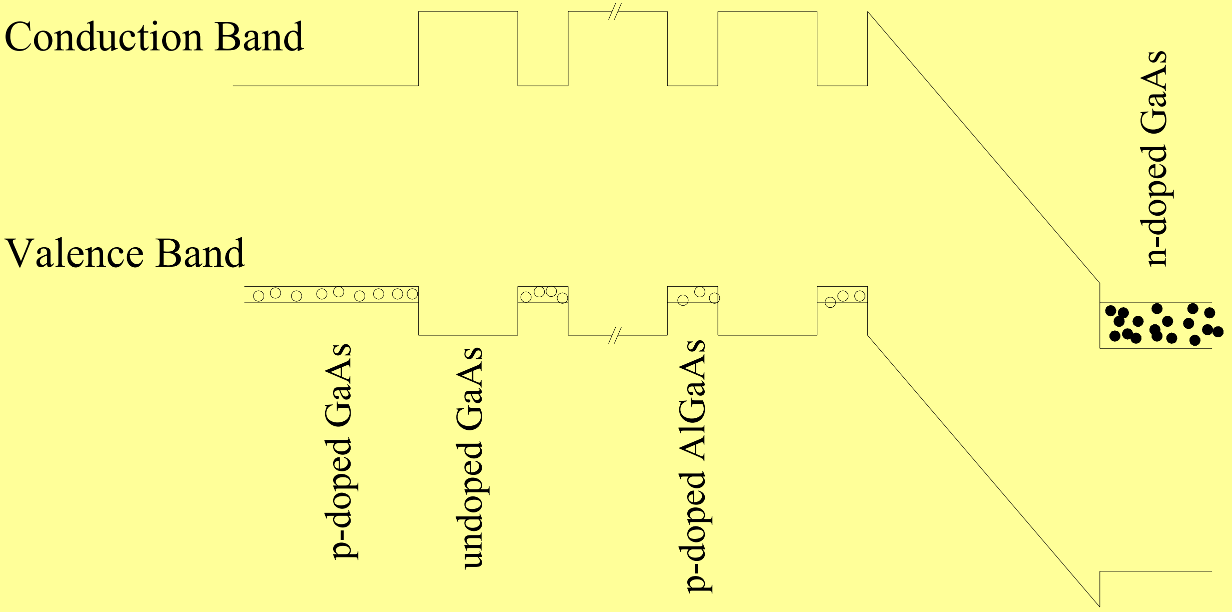
Improvements

Can introduce recombination well into the structure

Would allow use of AlGaAs emitters



Future Detectors



100 μm Threshold

Top Contact: GaAs p-doped 1×10^{19} cm^{-3}

25 Periods:

Emitters: 300 Å GaAs p-doped 1×10^{19} cm^{-3}

Barriers: 1000 Å $Al_{0.005}Ga_{0.995}As$ undoped

Bottom Barrier: 2000 Å $Al_{0.005}Ga_{0.995}As$ undoped

Bottom Contact: GaAs n-doped 1.1×10^{17} cm^{-3}

15 μm Threshold

Top Contact: GaAs p-doped 1×10^{19} cm^{-3}

24 Periods:

Emitters: 300 Å GaAs p-doped 1×10^{19} cm^{-3}

Barriers: 500 Å $Al_{0.12}Ga_{0.88}As$ undoped

Bottom Barrier: 2000 Å $Al_{0.12}Ga_{0.88}As$ undoped

Bottom Contact: GaAs n-doped 1.1×10^{17} cm^{-3}