InAs/GaSb Strained Layer Superlattice Detectors with nBn Design

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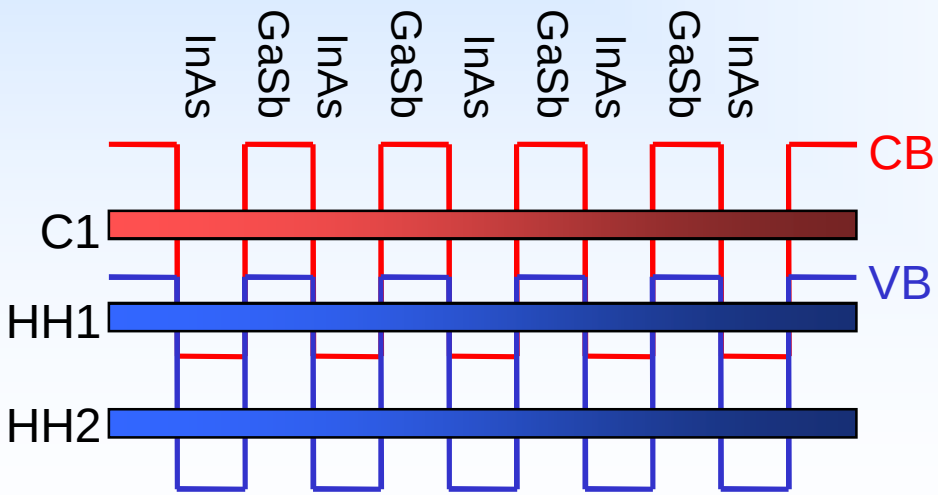
Outline

- ✓ Type-II InAs/GaSb SLS Photodetectors
- ✓ nBn Photodetector: The Concept and Timeline
- ✓ nBn Detector with Doped Absorber
- ✓ Conclusions
- ✓ References

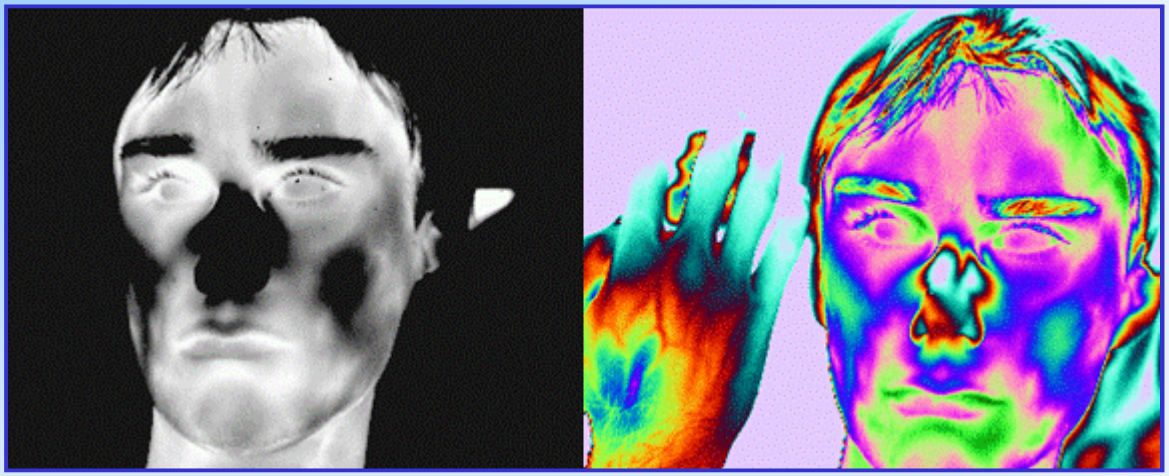
Motivation for Using SLS

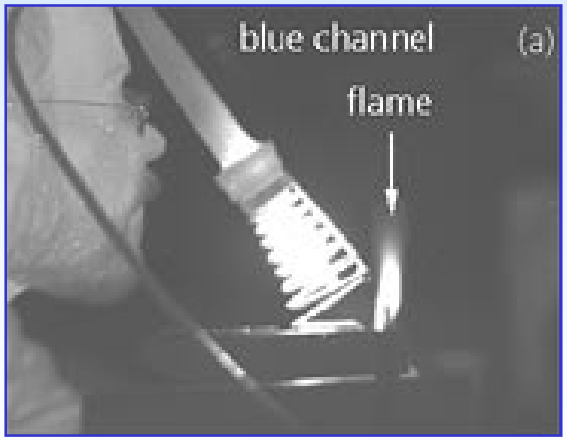
Characteristic	HgCdTe	InSb	Type II SLS	QWIPs	QDIPs
Normal incidence absorption	yes	yes	yes	no	yes
Operation Temperature	high	low	high	low	high
High Quantum Efficiency	yes	yes	yes	no	no
High Responsivity and Detectivity	yes	yes	yes	yes	yes
Multicolor Operation	yes	no	yes	yes	yes
Material Yield	low	low	high	high	high

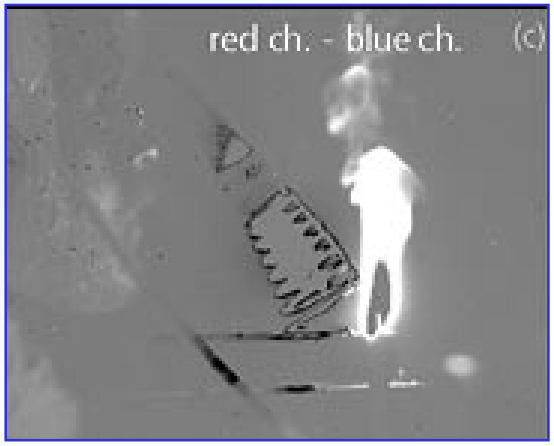


D.L. Smith and C. Mailhot, J. Appl. Phys. ***62****, 2545 (1987)*

Application of SLS Devices





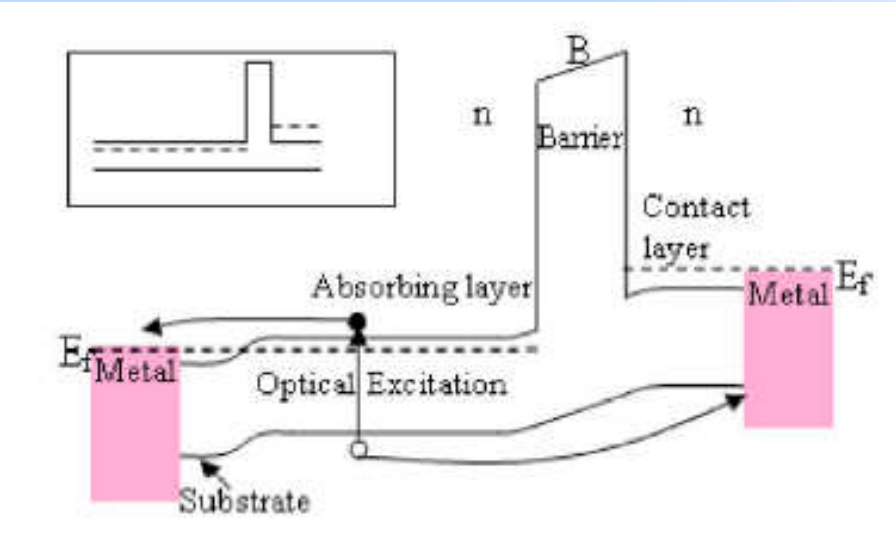


Web site of Center for Quantum Devices (NWU)
Plis et al, Proc. of SPIE vol. 6940 (2008)
*Rehm et al, Opto-Electron. Rev., **14**, no. 1 (2006)*

nBn Photodetector:
The Concept and Timeline

nBn Detector: The Concept

- ✓ Designed to operate in flat-band condition
- ✓ Minimal valence band offset



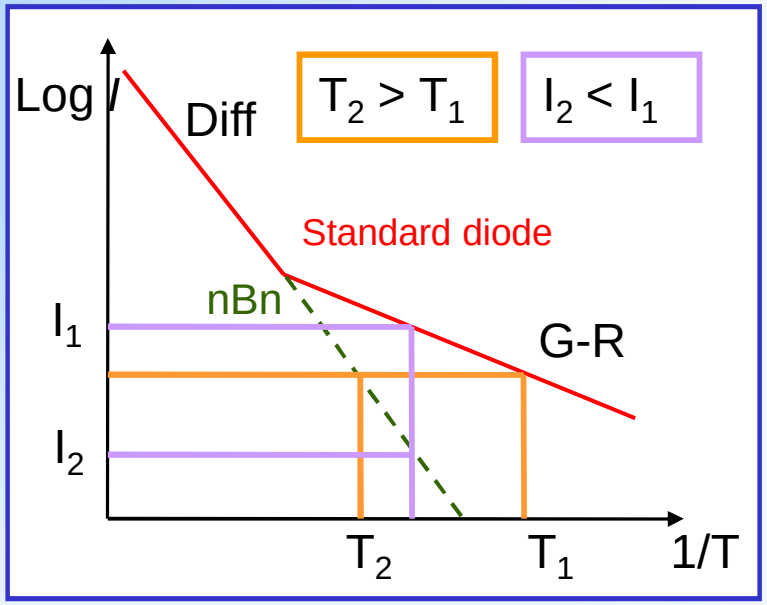
SRH G-R currents are eliminated

Surface currents are eliminated
No need for passivation

Realization of dual-color detection is simple

S. Maimon and G. W. Wicks, Appl. Phys. Lett. 89, 151109 (2006)

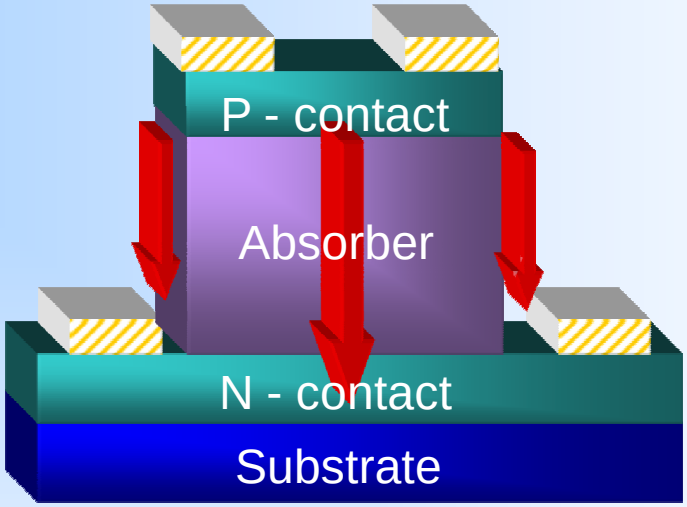
nBn Detector: The Concept

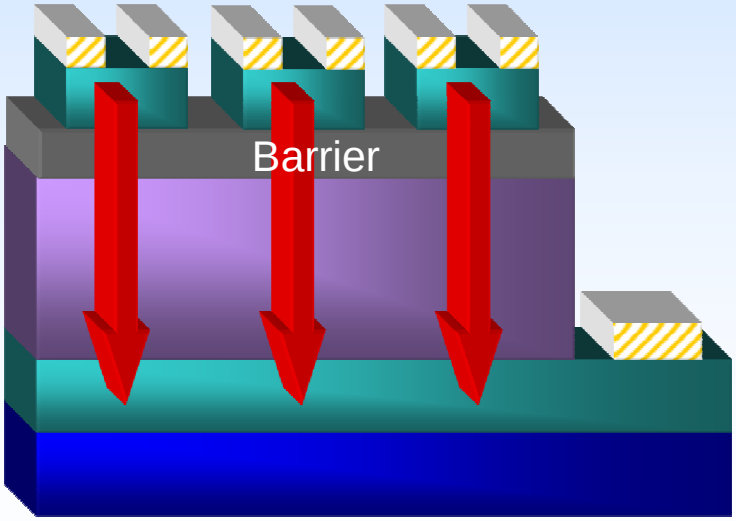


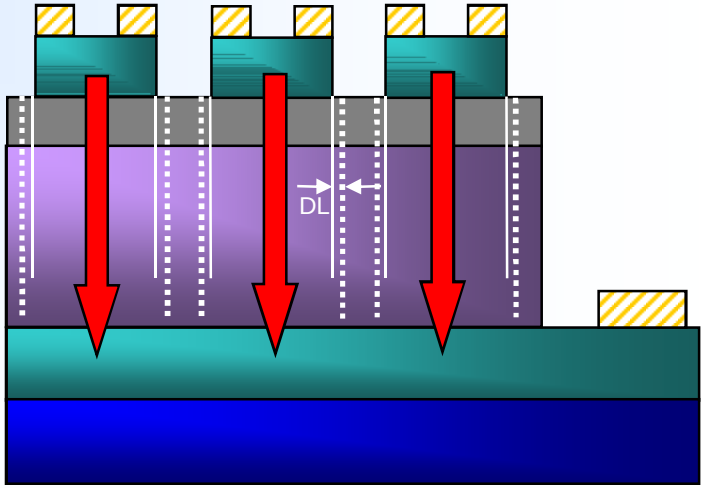
Higher $T_{operational}$ with the same performance

Better performance at the same $T_{operational}$

nBn Detector: The Concept

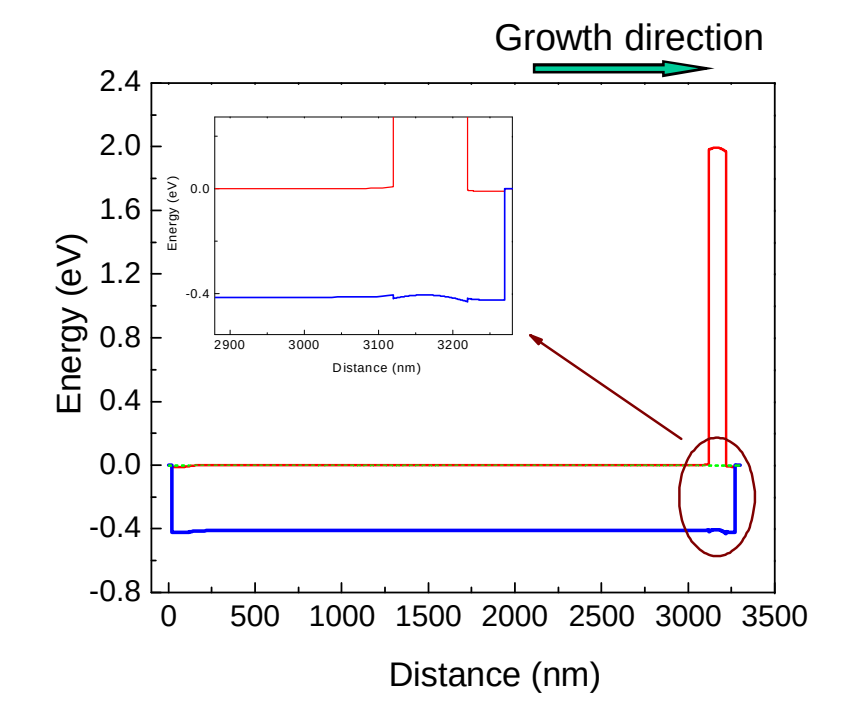




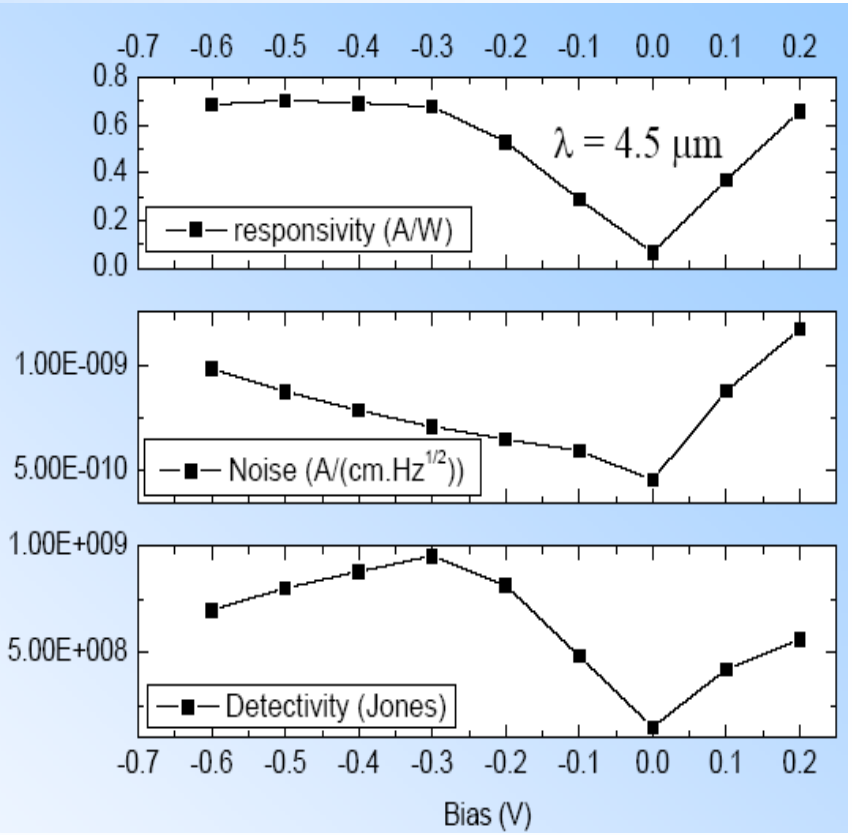


nBn Detector: First Results

✓ InAs-based nBn detector*



✓ InAs/GaSb SLS detector with nBn design**

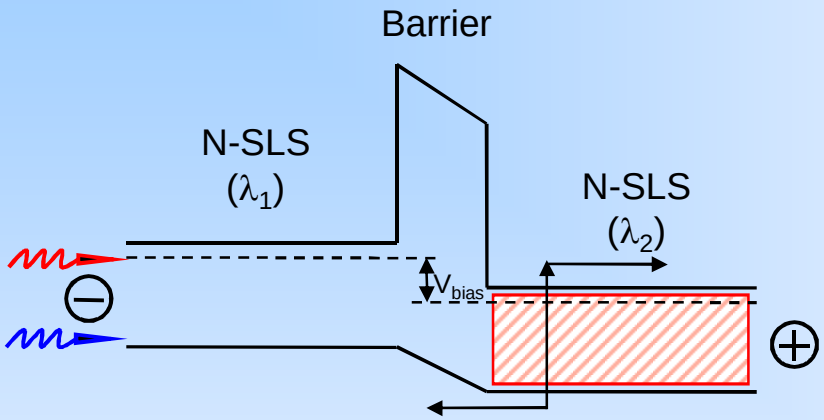


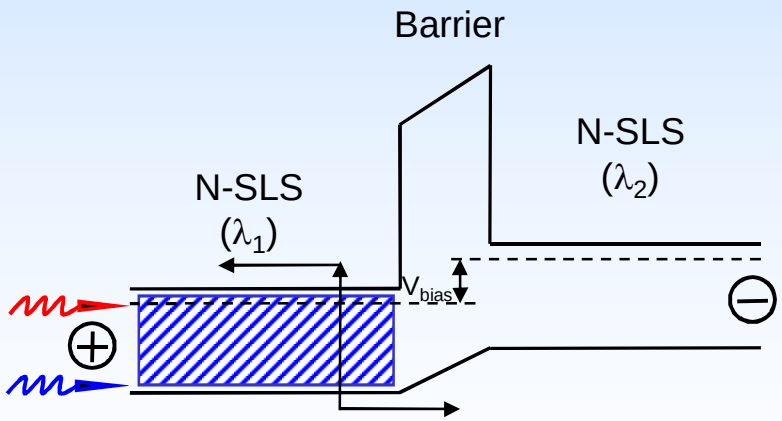
✓ BLIP temperature increase by 100K

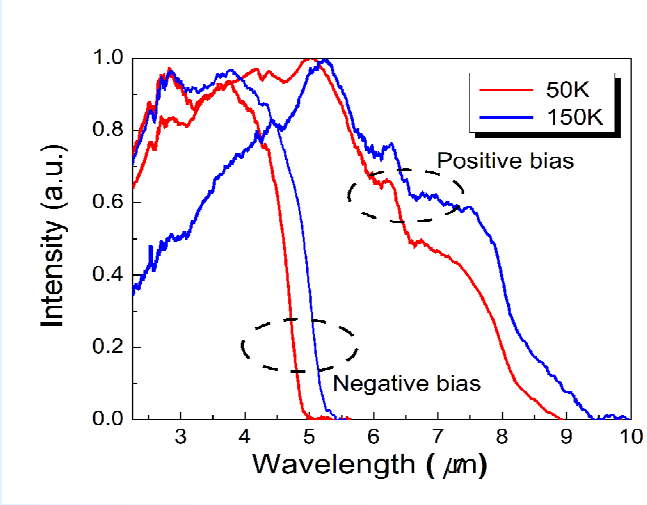
*S. Maimon and G. W. Wicks, Appl. Phys. Lett. 89, 151109 (2006)

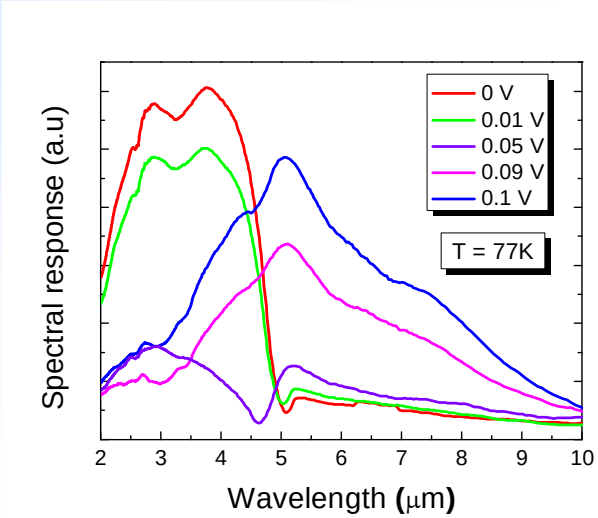
**Rodriguez et al (UNM), Appl. Phys. Lett. 91, 43514 (2006)

nBn Detector: Dual-Color Operation



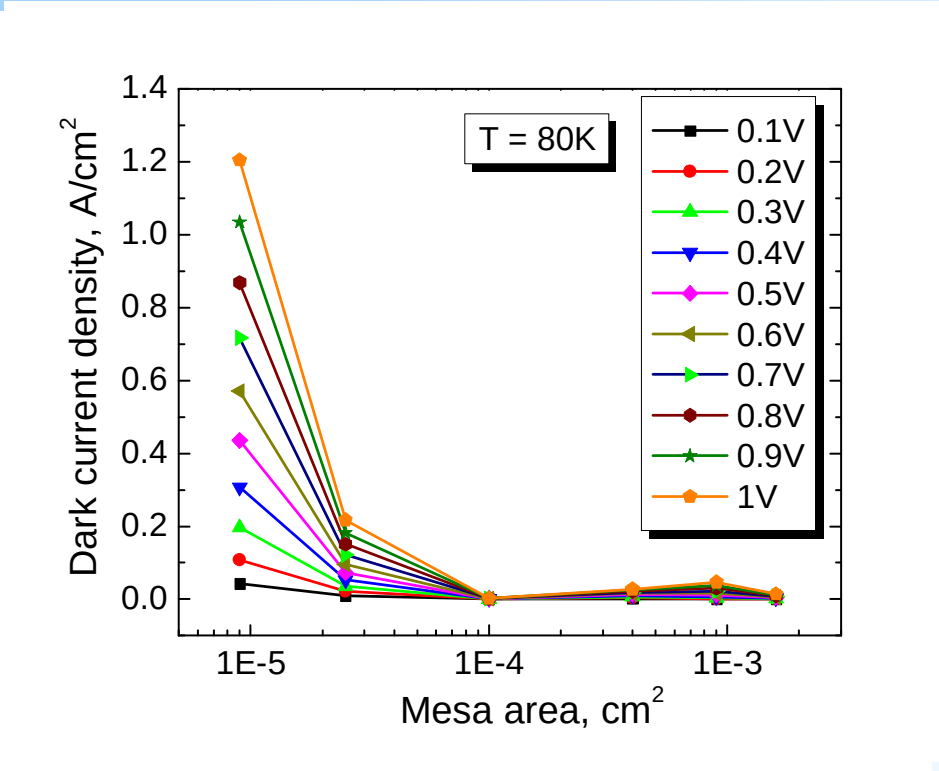


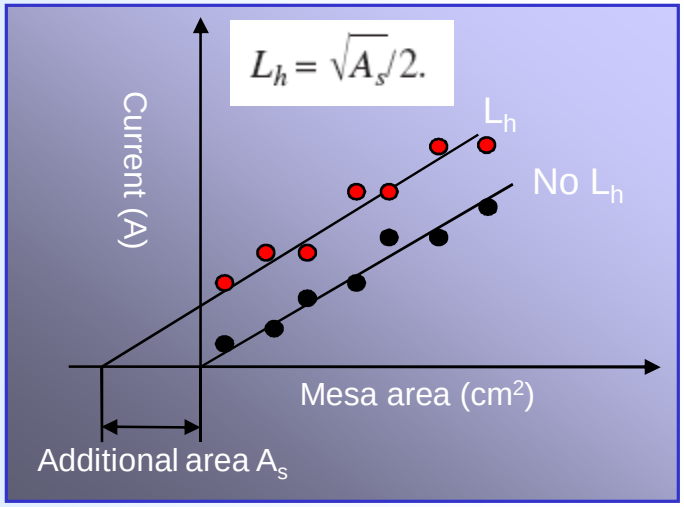




Khoshakhlagh et al (UNM), Appl. Phys. Lett. ***91****, 263504(2007)*

nBn Detector: Lateral Diffusion



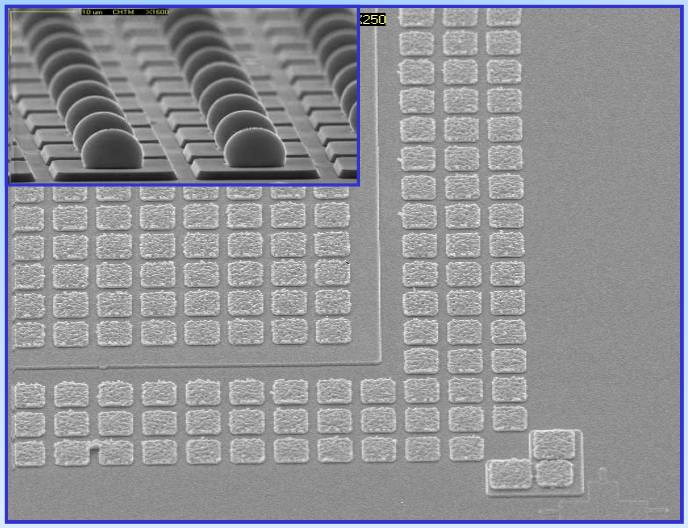


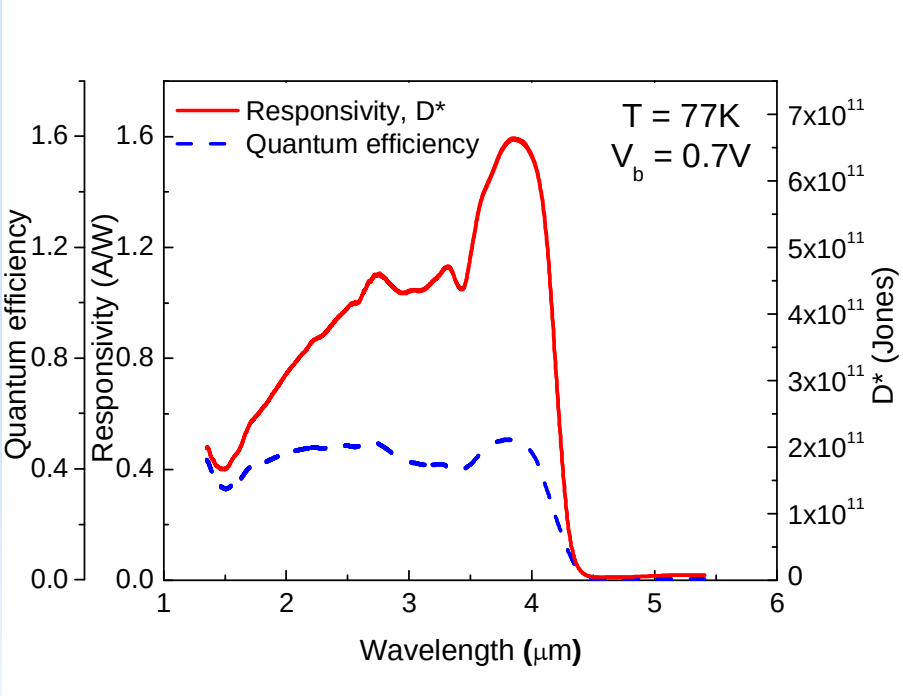
$$A_s = (d + 2L_h)^2 - d^2$$

L_h ranges
from ~101 μm (77K, 0.6V)
to ~1 μm (250K, 0.6V)

Plis et al (UNM), Appl. Phys. Lett. ***93****, 123507 (2008)*

nBn Detector: MWIR InAs/GaSb SLS FPA





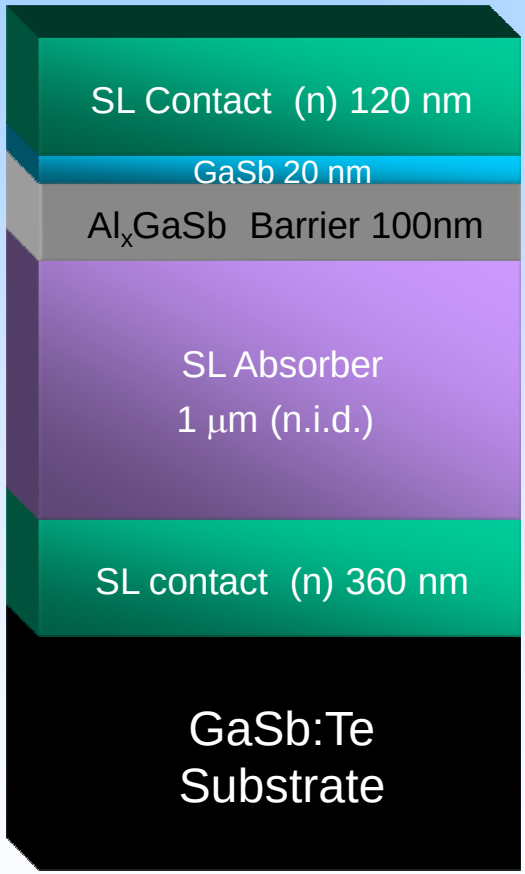
QE ~ 52%, R = 1.6 A/W
D* ~ 7 x 10^{11} Jones
(V_b = 0.7V, 3.8 μm, 77K)

Measurements with collaboration of QmagiQ LLC

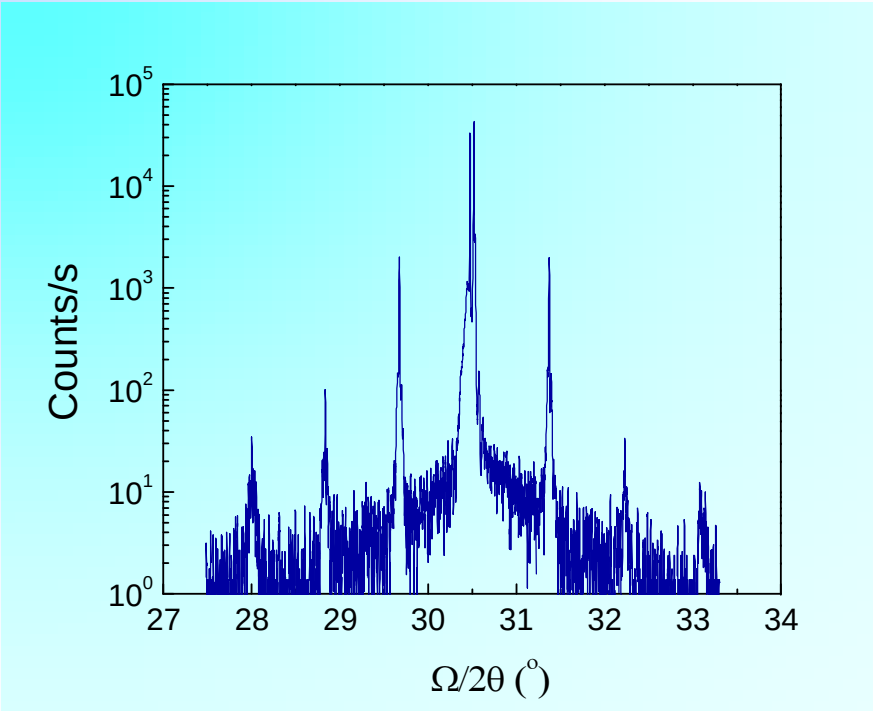
Kim et al (UNM), Appl. Phys. Lett. ***92****, 183502 (2007)*

Motivation of Study

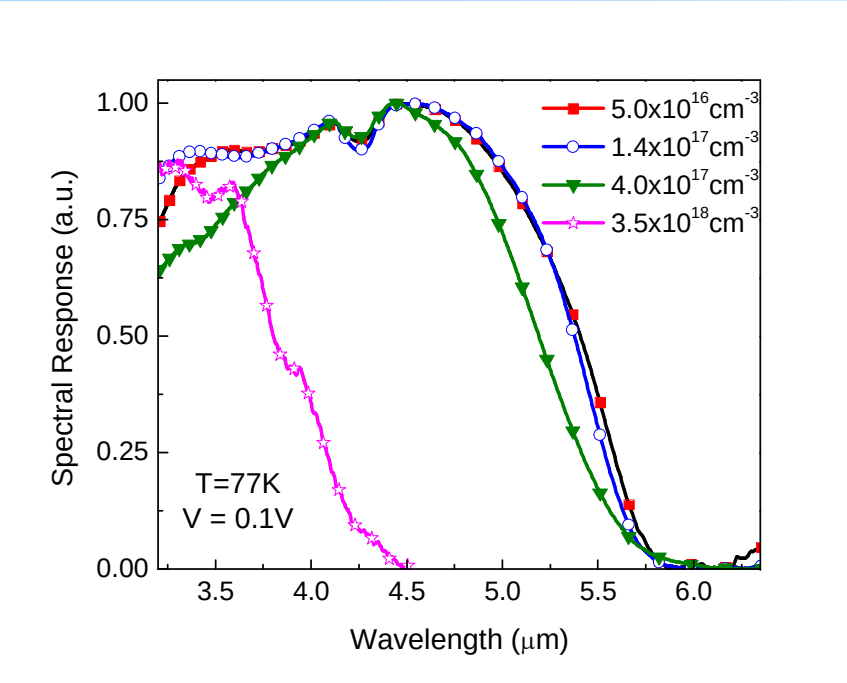
nBn Detector with Doped Absorber

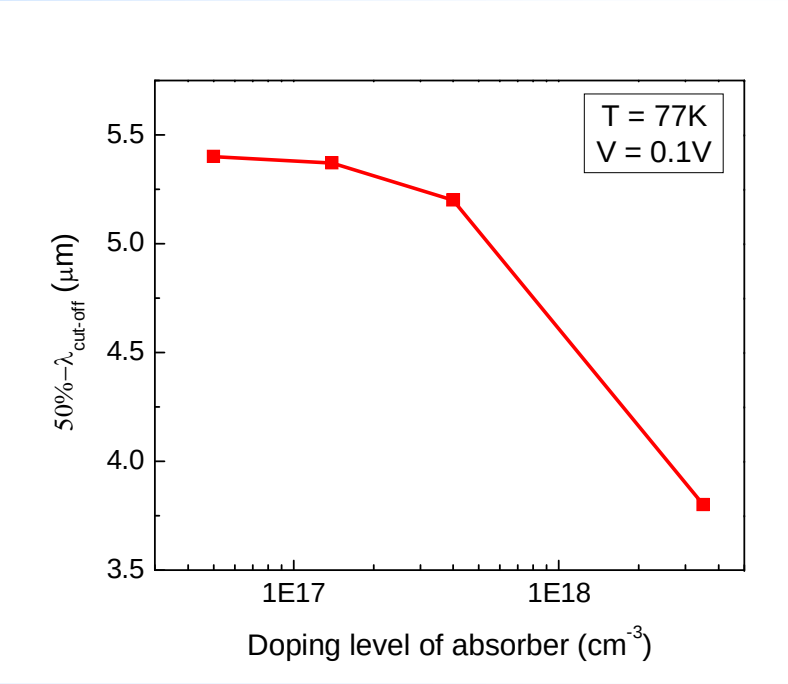


✓ The doping level is the determinative parameter for electrical and optical quality of pin diode



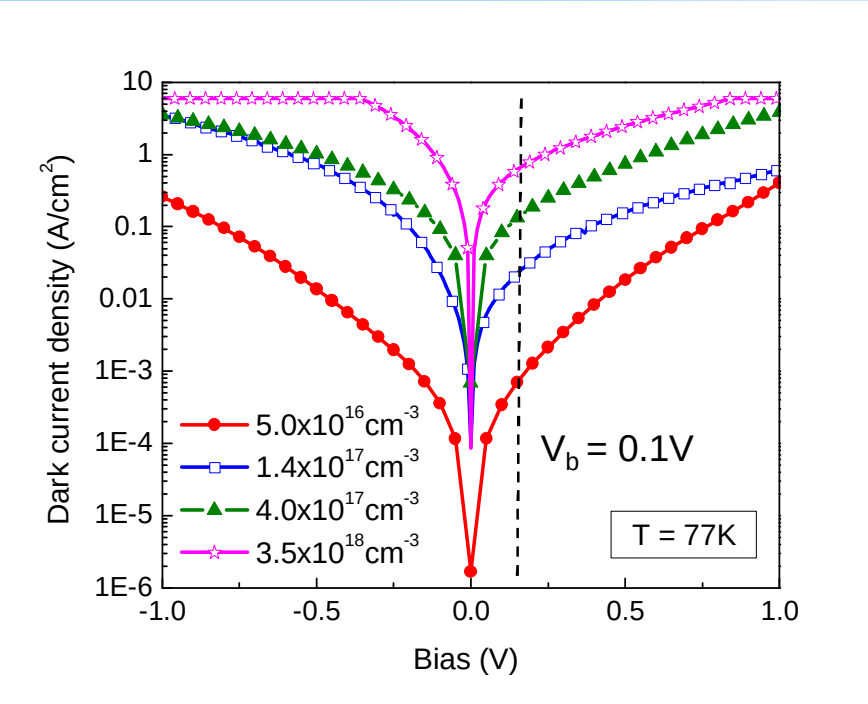
nBn Detector with Doped Absorber

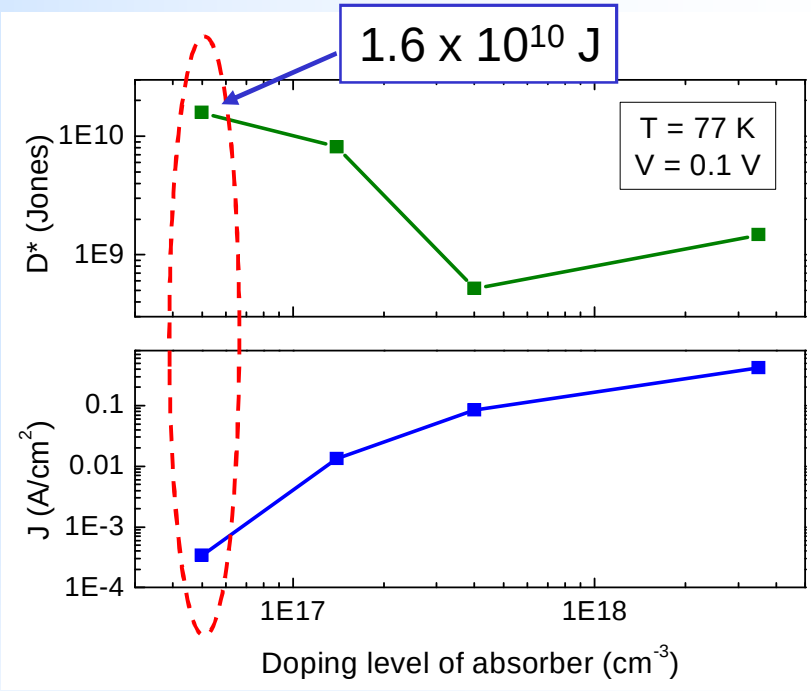




Detector with heavily doped (3.5×10^{18} cm^{-3}) absorbing region demonstrated a larger optical bandgap ($\lambda_{50\%} \sim 3.8$ μm) due to the Moss-Burstein effect

nBn Detector with Doped Absorber

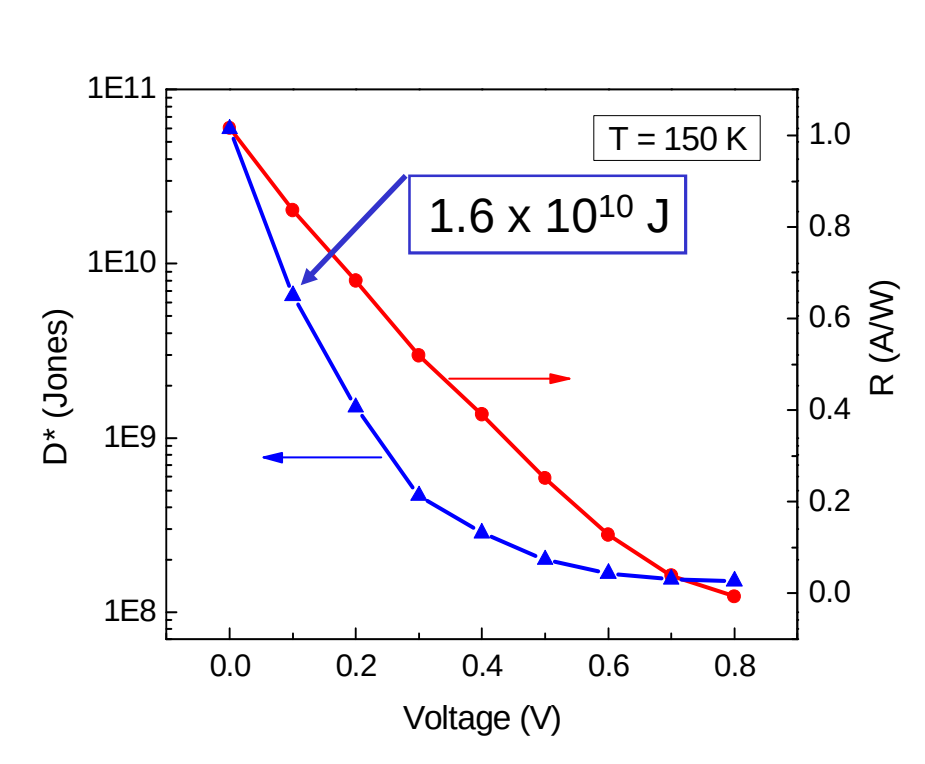


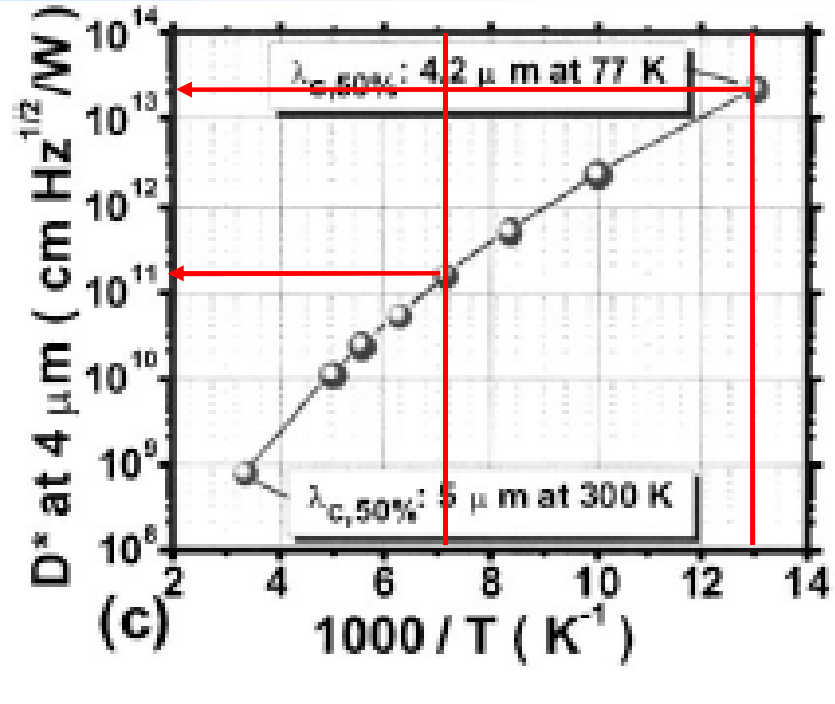


Doping concentration: 5 x 10^{16} cm^{-3} → 3.5 x 10^{18} cm^{-3}

Dark current density: ~ 0.3 mA/cm^2 → ~ 0.3 A/cm^2

nBn Detector with Doped Absorber



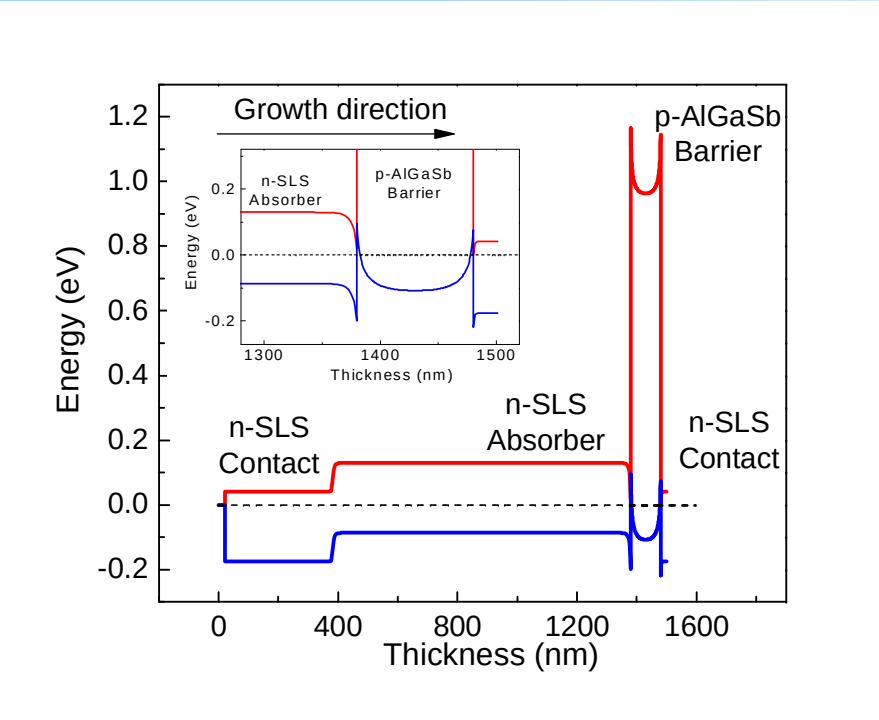


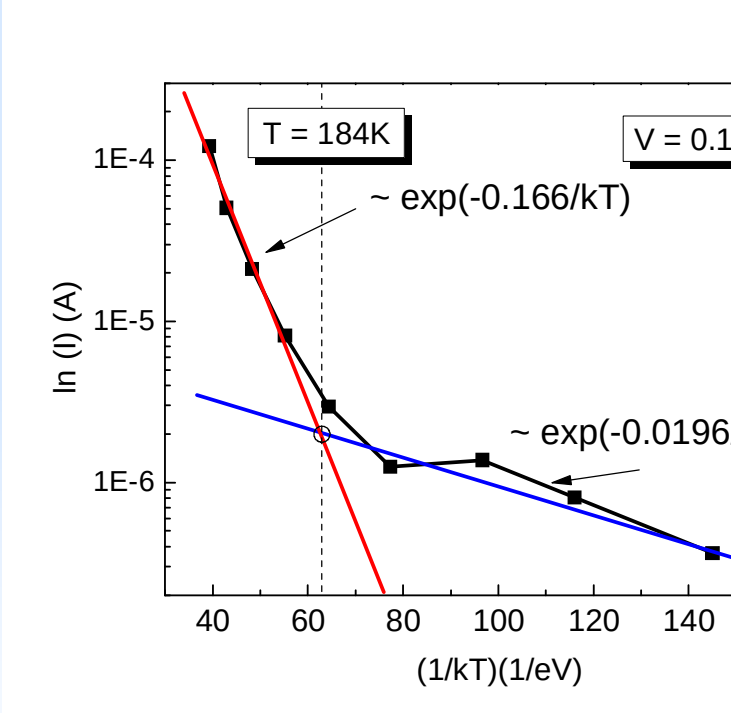
R = 1 A/W and D* = 6 x 10^{10} Jones (zero bias, 150K)

No degradation of D* with temperature within (0-100 mV) bias range

Wei et al, Appl. Phys. Lett. ***86****, 233106 (2005)*

nBn Detector with Doped Absorber





Measurements with collaboration of UIC
*Modeling was performed with next**nano** TM*

Conclusion and Future Work

- The development of nBn based detectors for the MWIR spectral region using InAs/GaSb SLS has been presented

- Performance of nBn detectors as a function of BKG carrier concentration in the absorbing region of nBn device has been investigated

- Device with non-intentionally doped absorption region had demonstrated the best signal-to-noise ratio
  - J = 0.3 mA/cm^2 (77K and 0.1V)
  - D* = 1.6 x 10^{10} Jones (77K-150K and 0.1V)

- No significant degradation of D* with temperature within (0-100 mV) bias range was observed

- Future work:
  - investigation of DL behavior in nBn structures with doped absorbing region

nBn Detector
The Summary and Recent Work

✓P C Klipstein, *patent* of barrier devices in InAsSb and superlattice: WO 2005/004243 A1

✓S. Maimon, *patent* on reduced dark current photodetectors No. US 2007/0215900 A1

✓ Maimon and Wicks, Appl. Phys. Lett. **89**, 151109 (2006)
nBn detector concept is proposed
Fabrication of nBn detector with InAs bulk active region

✓ Rodriguez *et al (UNM)*, Appl. Phys. Lett. **91**, 043514 (2007)
Implementation of nBn concept on InAs/GaSb SLS

✓ Khoshakhlagh *et al (UNM)*, Appl. Phys. Lett. **91**, 263504 (2007)
Fabrication of dual-color nBn based InAs/GaSb SLS detector

✓*Kim et al (UNM), Appl. Phys. Lett.* ***92****, 183502 (2007)*
MWIR FPA camera based on InAs/GaSb SLS with nBn design

✓*Plis et al (UNM), Appl. Phys. Lett.* ***93****, 123507 (2008)*
Investigation of lateral diffusion issues in MWIR nBn structures

✓*P. Klipstein, Proc. of SPIE, vol. 6940 (2008)*
Comprehensive theoretical investigation of xBn structures