Lighting up the Semiconductor World…

Simulation of Type-II Quantum Well Photodetectors

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Applicable Models and Features

Input command looping technique to set up 150 pairs of coupled type-II MQW.

Type-II MQW optical gain/absorption spectrum from complex-MQW optical gain model.

Design of absorption spectrum by adjusting type-II band alignments.

Effective mini-band model based on quantum mechanical calculation.

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Tutorial example

* Structure similar to

R. Sidhu, N. Duan, J. C. Campbell, and A. L. Holmes, Jr.,
"A 2.3um CUTOFF WAVELENGTH PHOTODIODE ON InP USING LATTICE-MATCHED GaInAs-GaAsSb TYPE-II QUANTUM WELLS,"
2005 International Conference an Indium Phosphide and Related Materials,
p. 148, 2005.
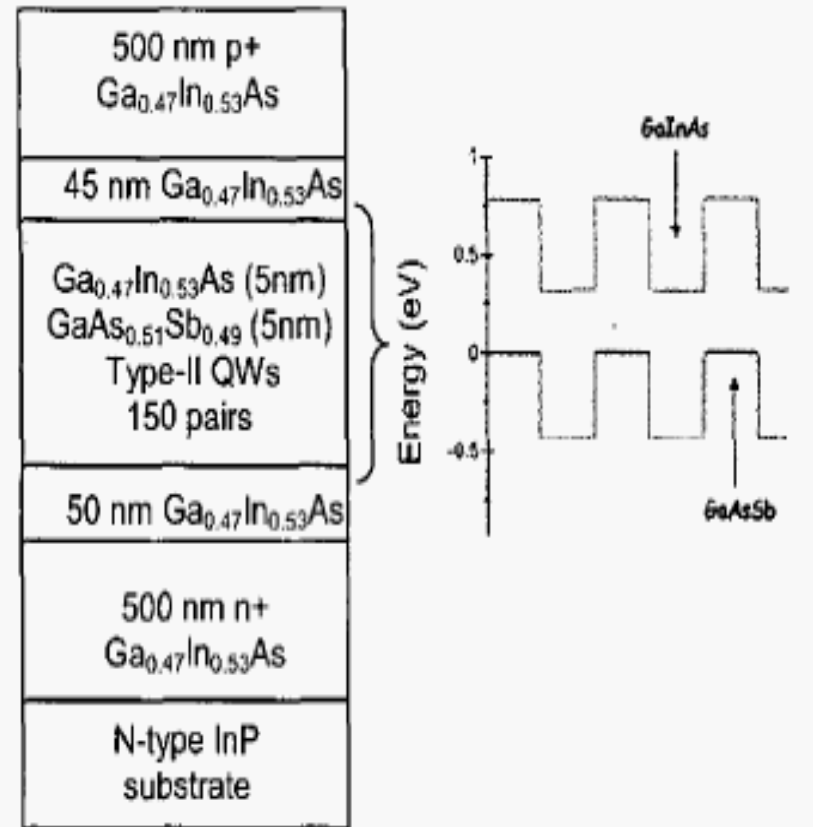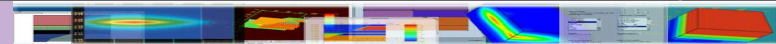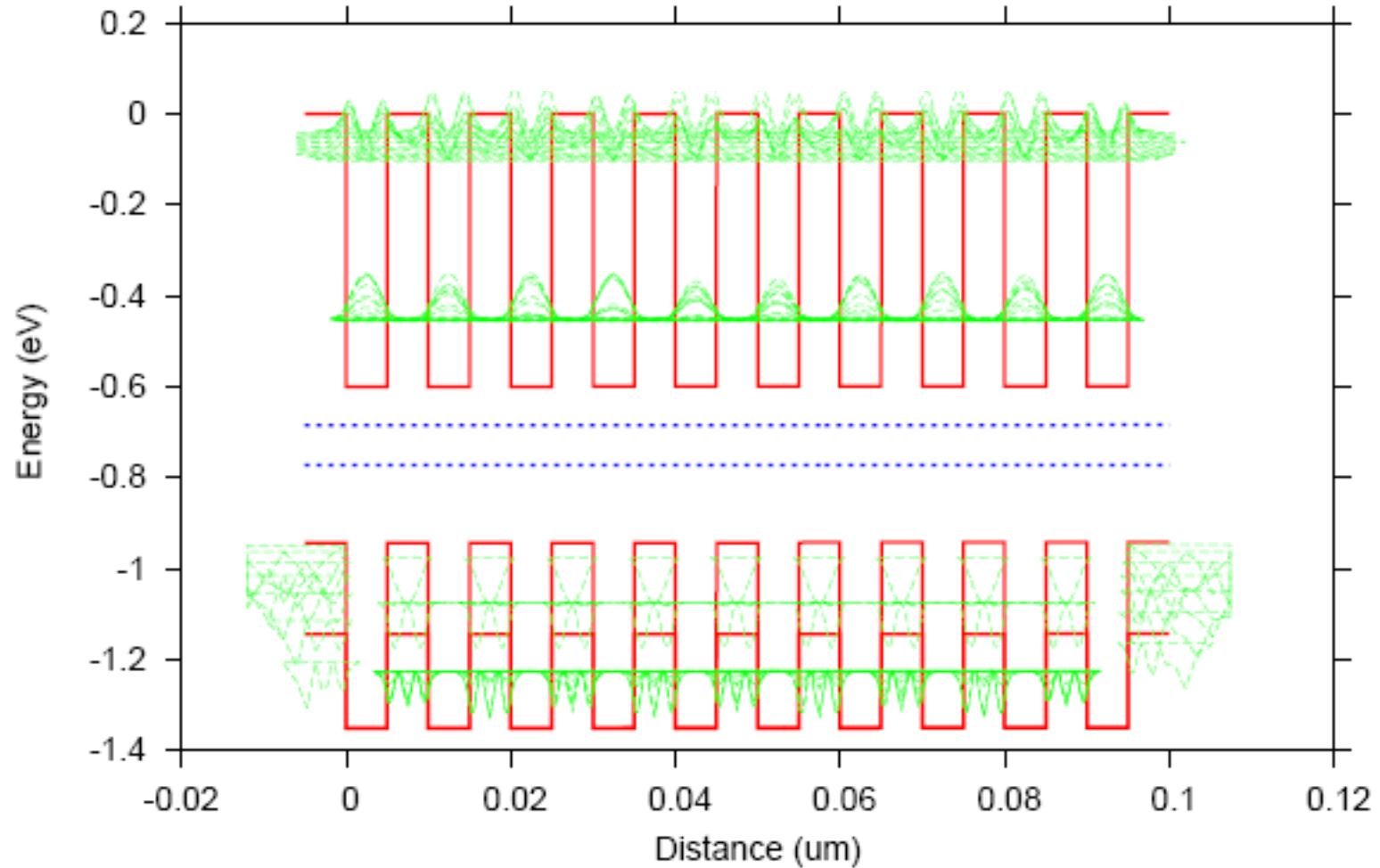
* Key adjustable parameters: band-offset and mobility.

500 nm p+
$Ga_{0.47}In_{0.53}As$

45 nm $Ga_{0.47}In_{0.53}As$

$Ga_{0.47}In_{0.53}As$ (5nm)
$GaAs_{0.51}Sb_{0.49}$ (5nm)
Type-II QWs
150 pairs

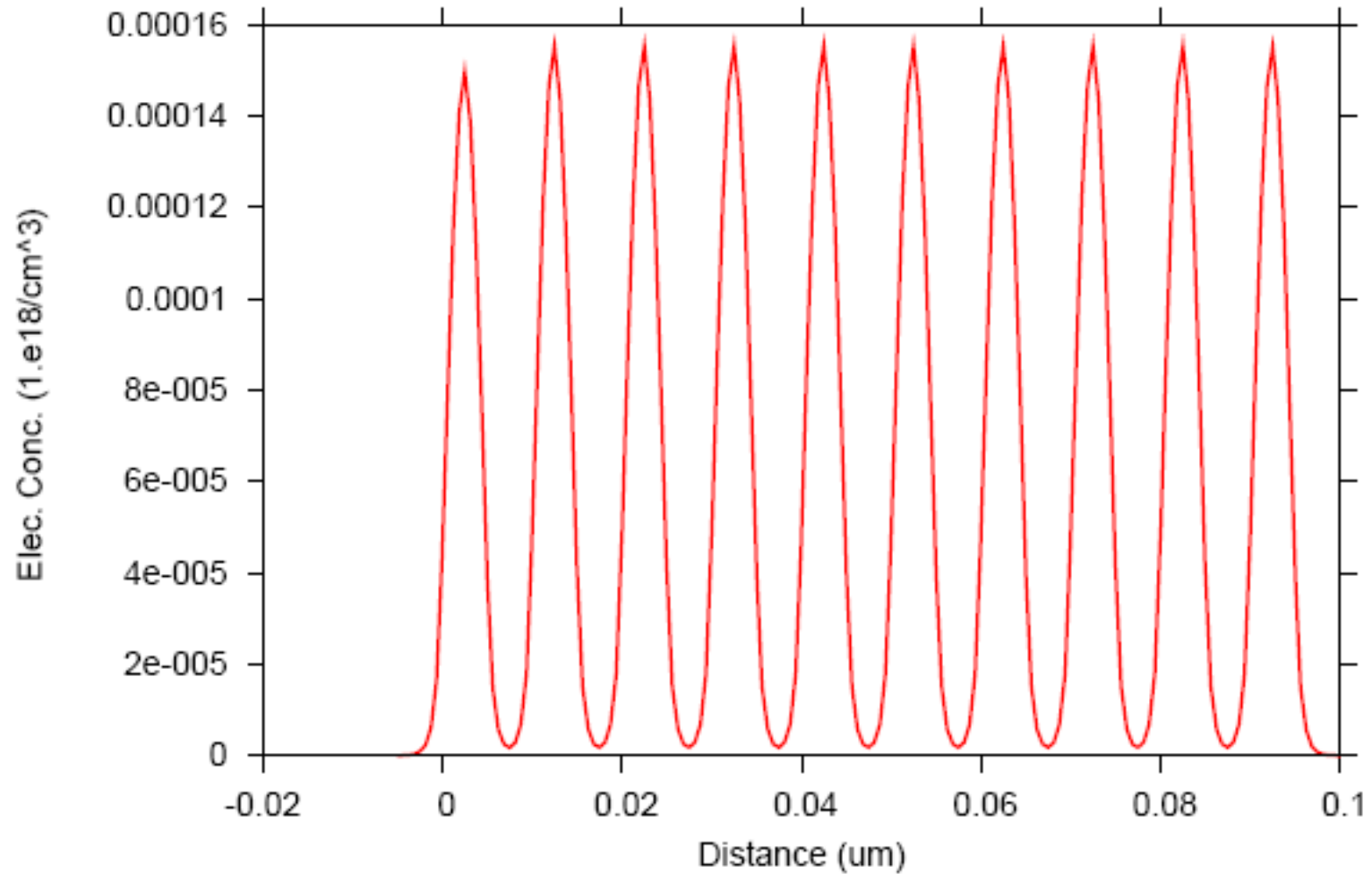50 nm $Ga_{0.47}In_{0.53}As$

500 nm n+
$Ga_{0.47}In_{0.53}As$

N-type InP substrate

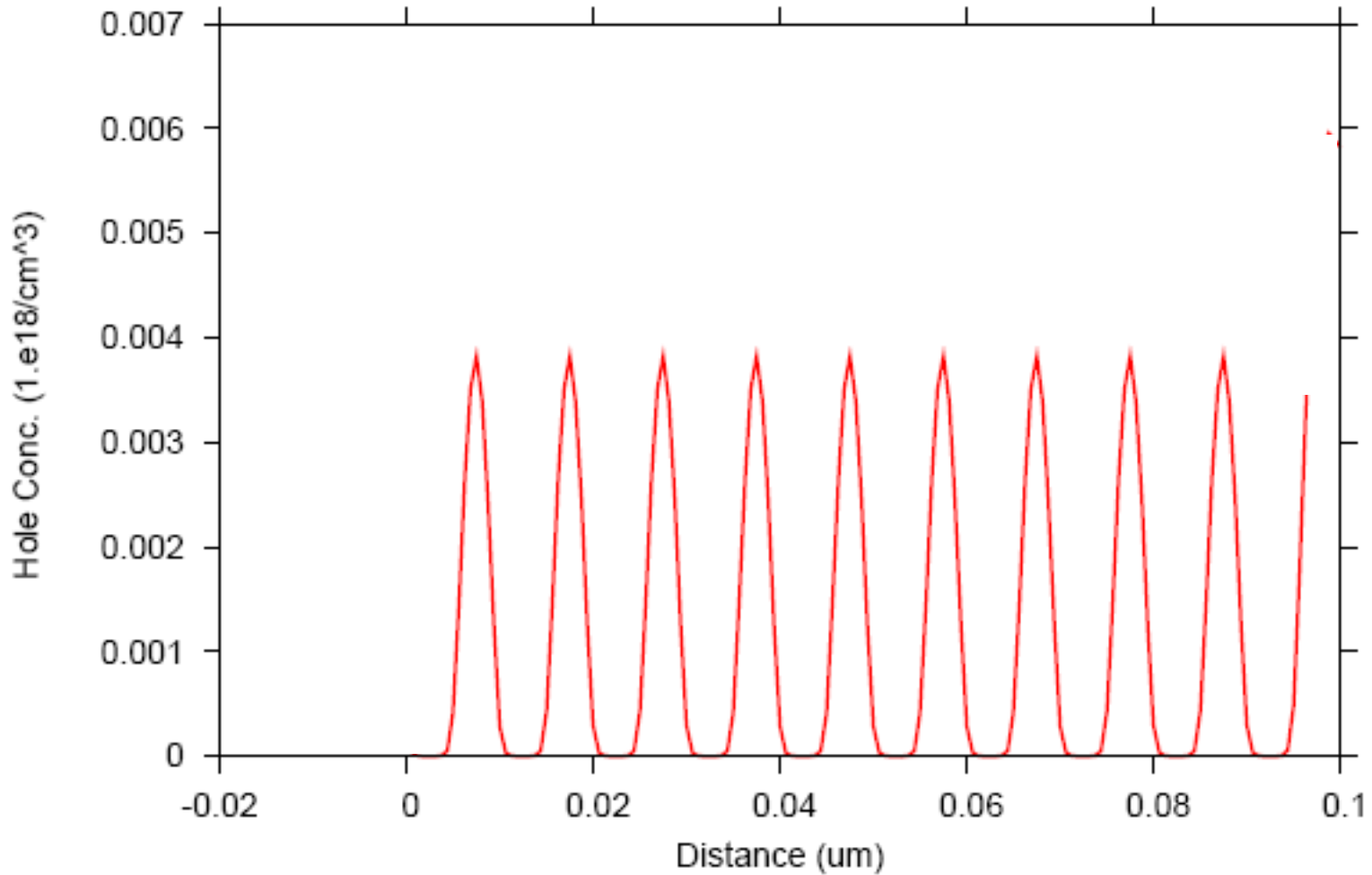Figure 1. Schematic device structure and band lineup between GaInAs-GaAsSb

Type-II QWPD: band structure design
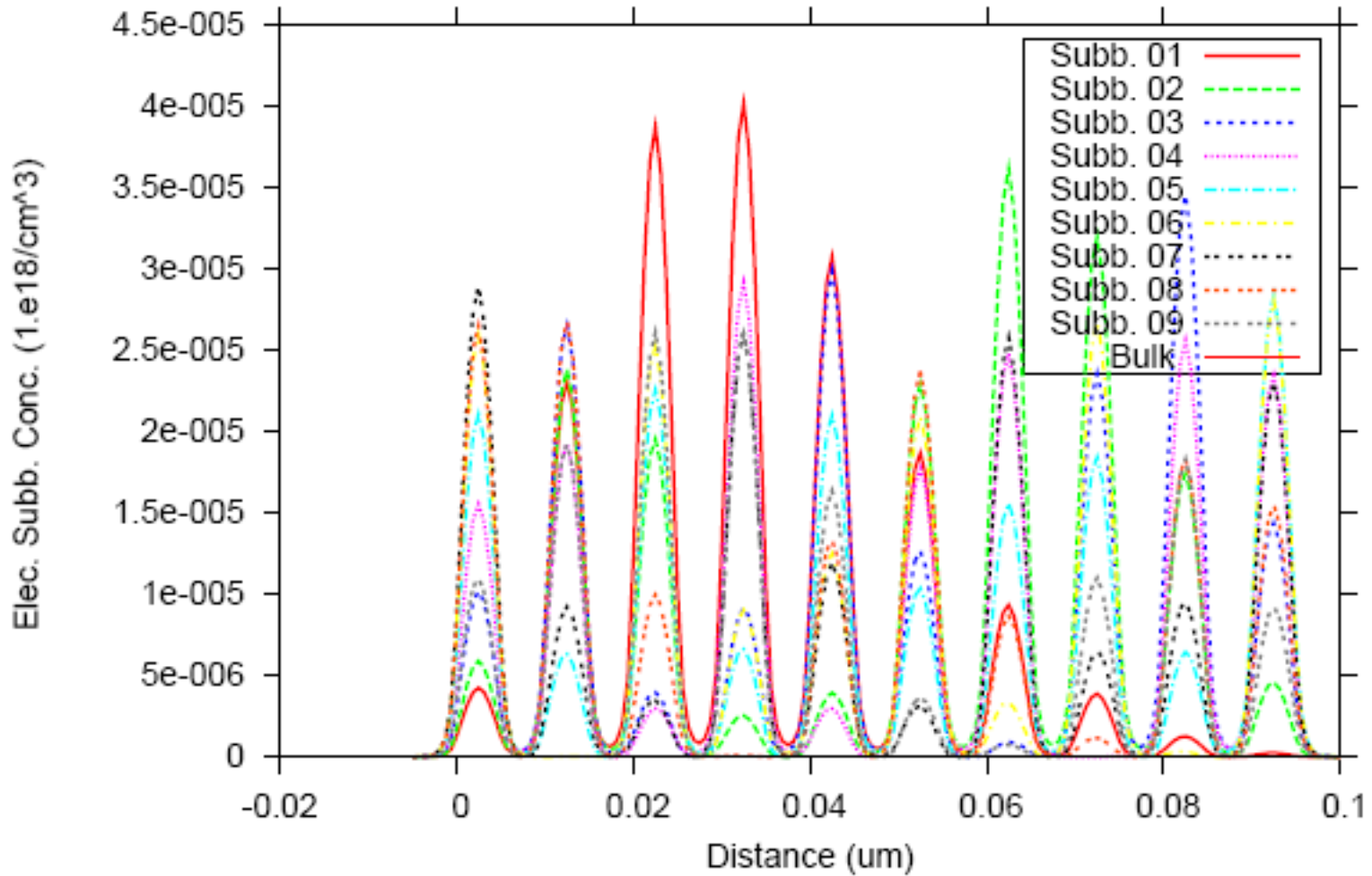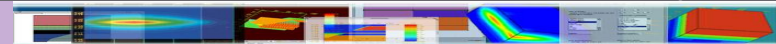
CROSLIGHT
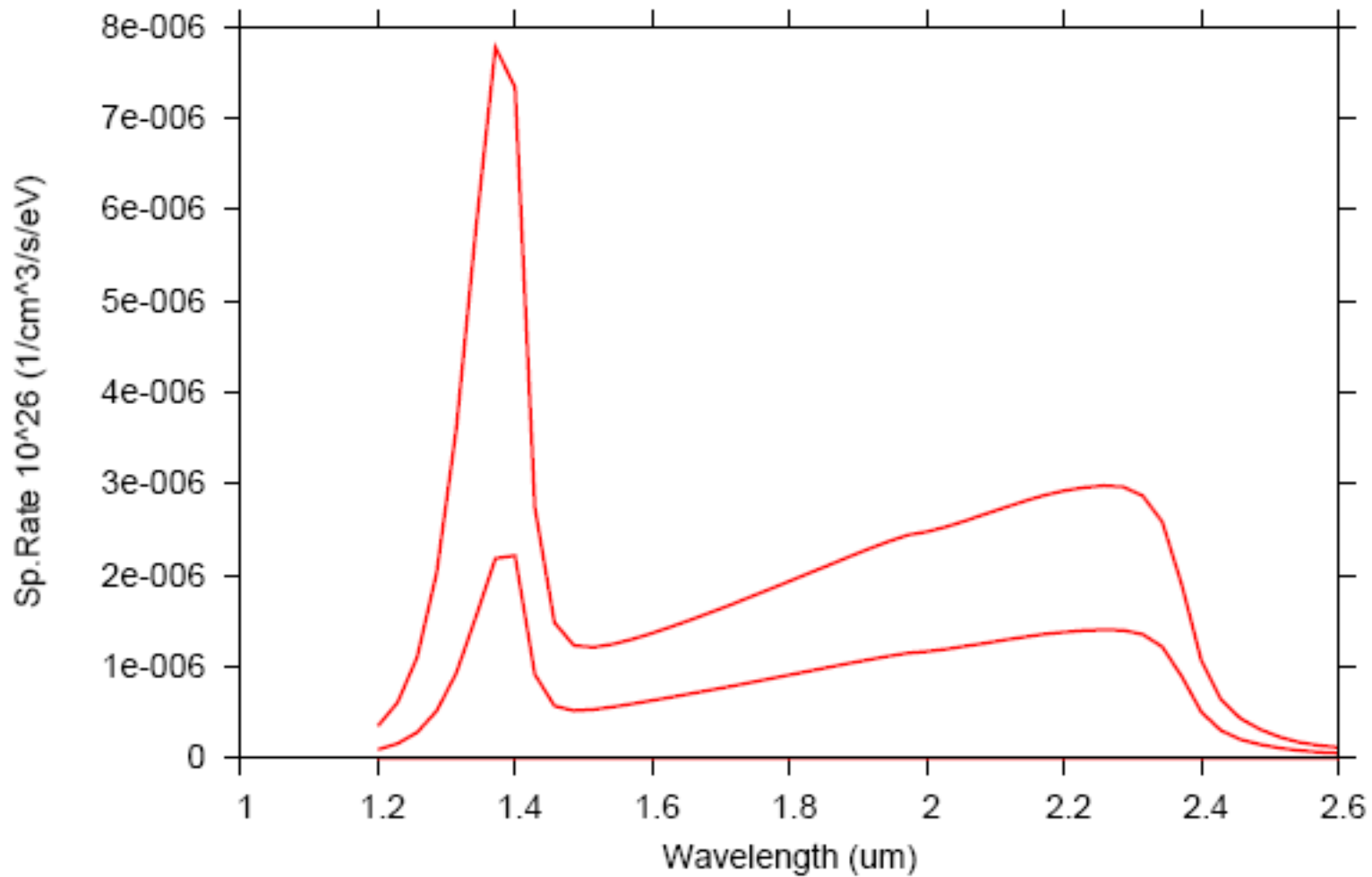Software Inc.

Type-II QWPD: electron densities
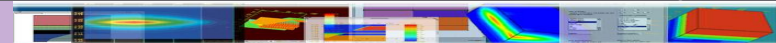
Type-II QWPD: hole densities

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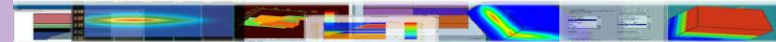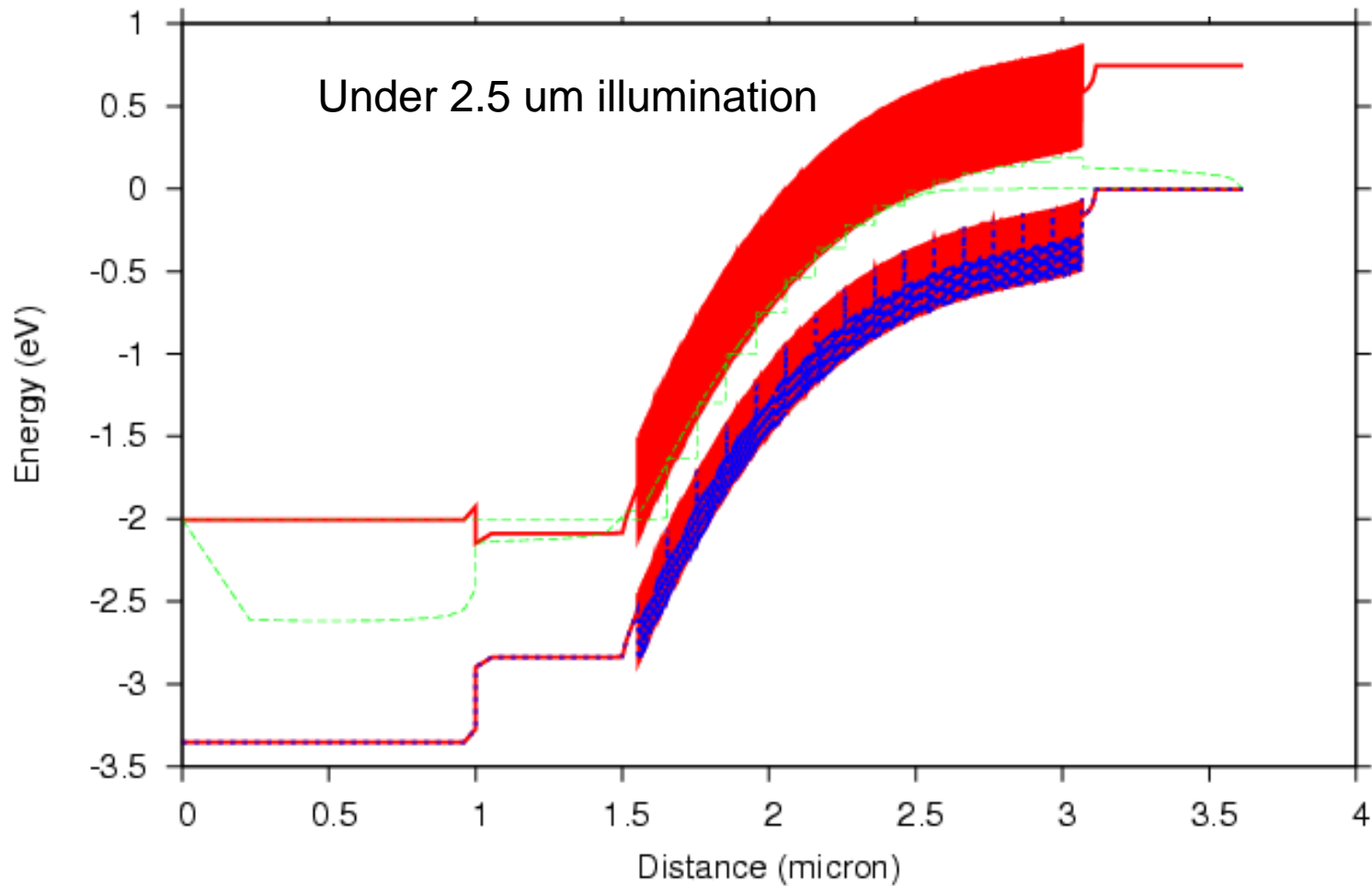# Type-II QWPD: electron subbands

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Type-II QWPD: optical gain or -absorption
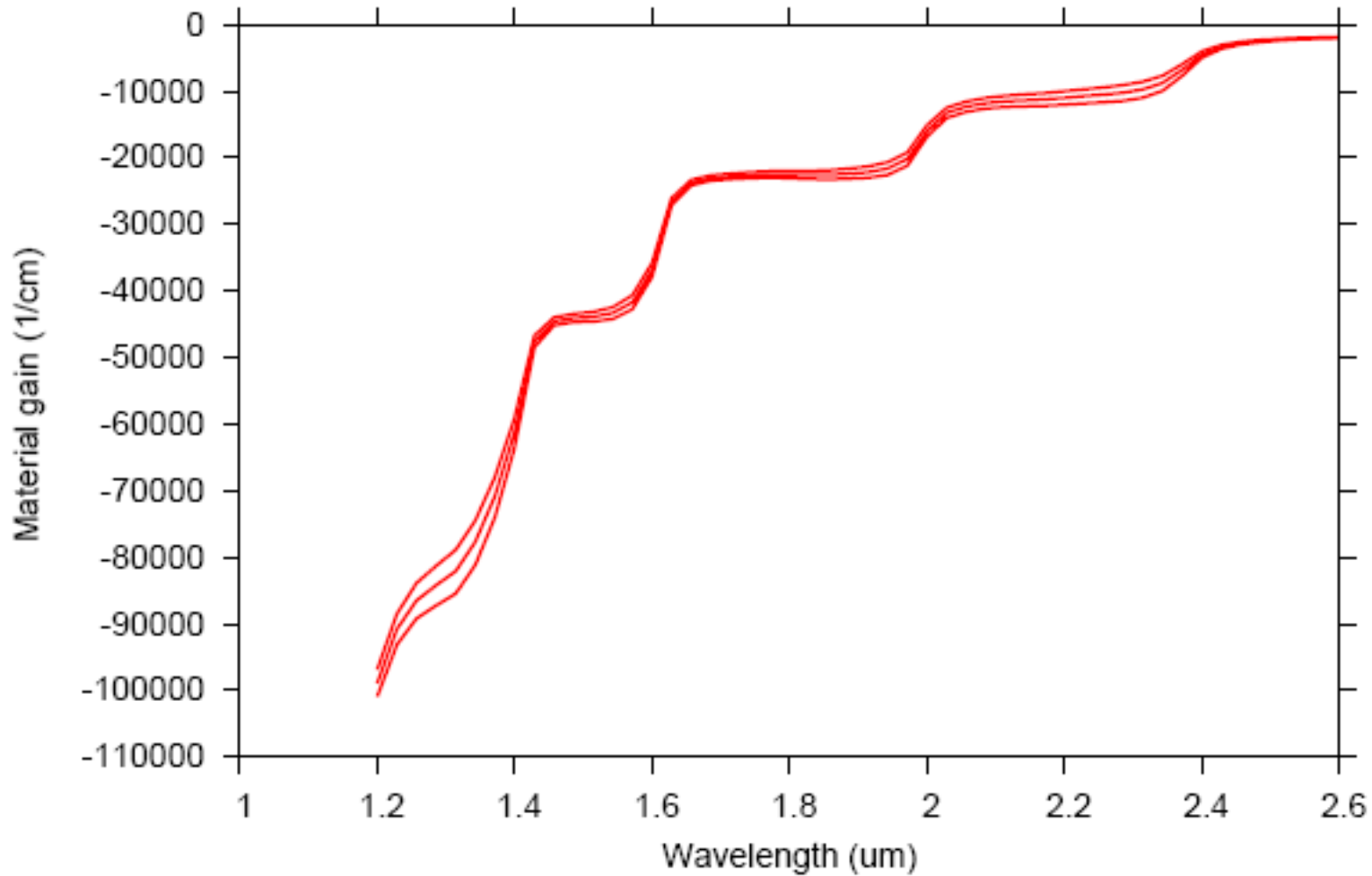
Type-II QWPD: spontaneous emission

Type-II QWPD: band diagram at 2 Volt

Under 2.5 um illumination

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Type-II QWPD: band diagram at 2 Volt

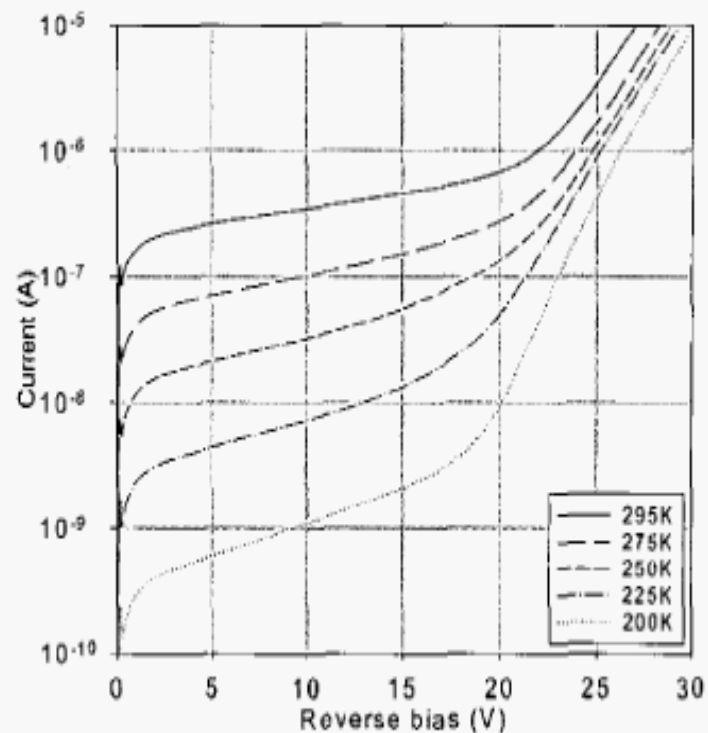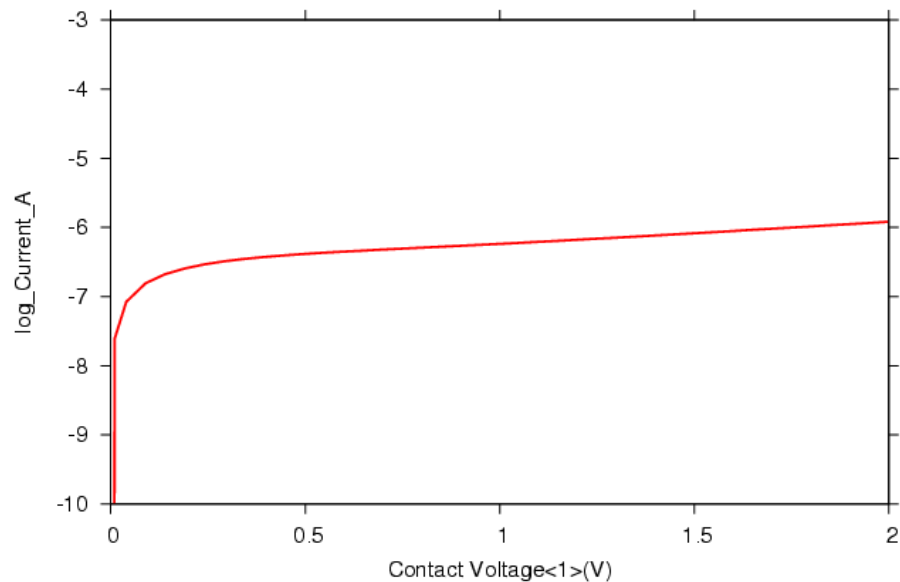Wavelength 1.3 um
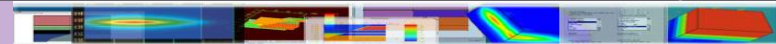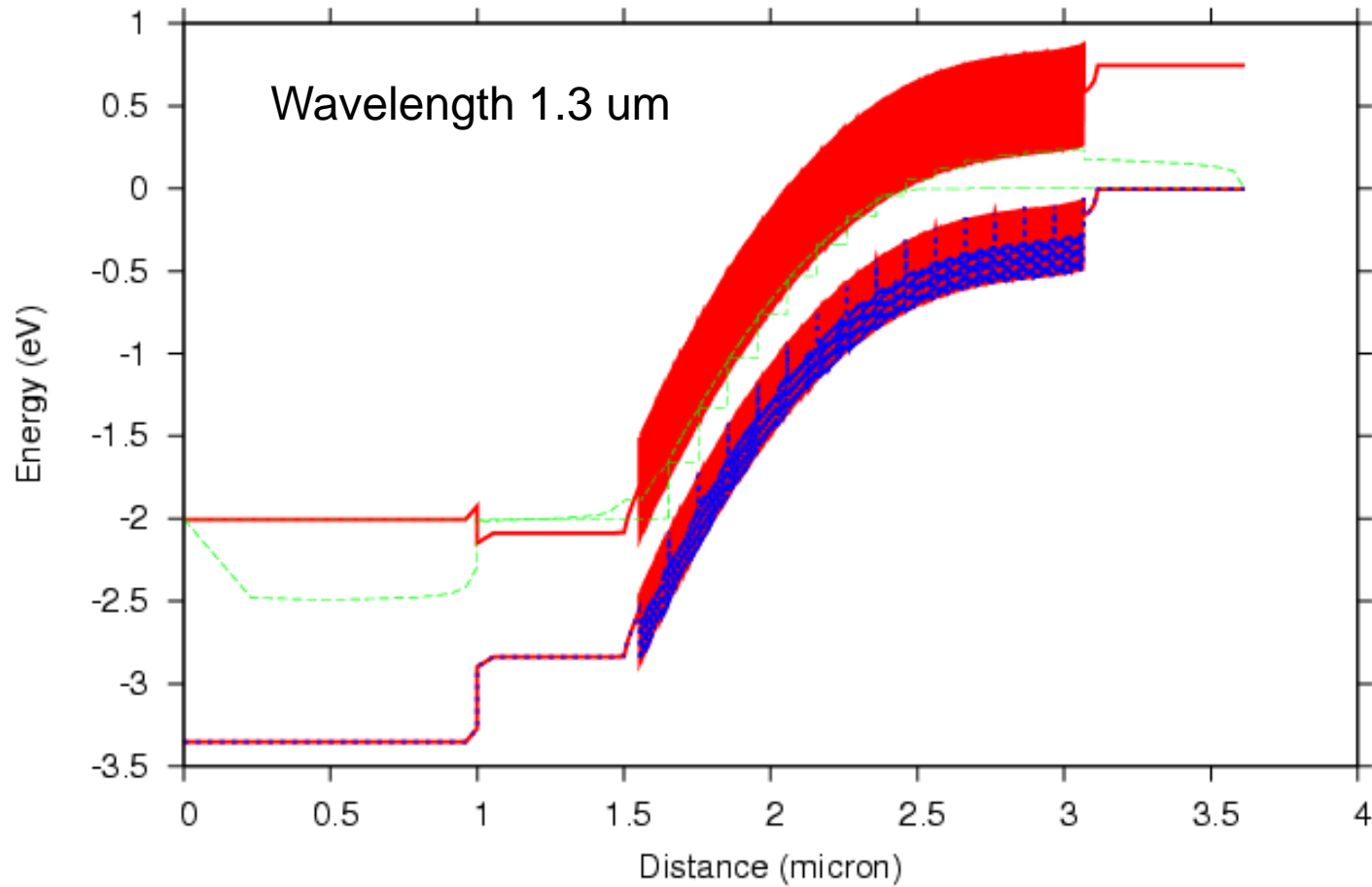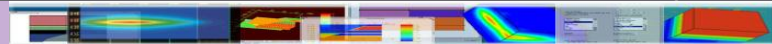
Type-II QWPD: dark current

Figure 2. Dark current vs. voltage from a 64μm diameter device, measured at 200K, 225K, 250K, 275K, and 295K.
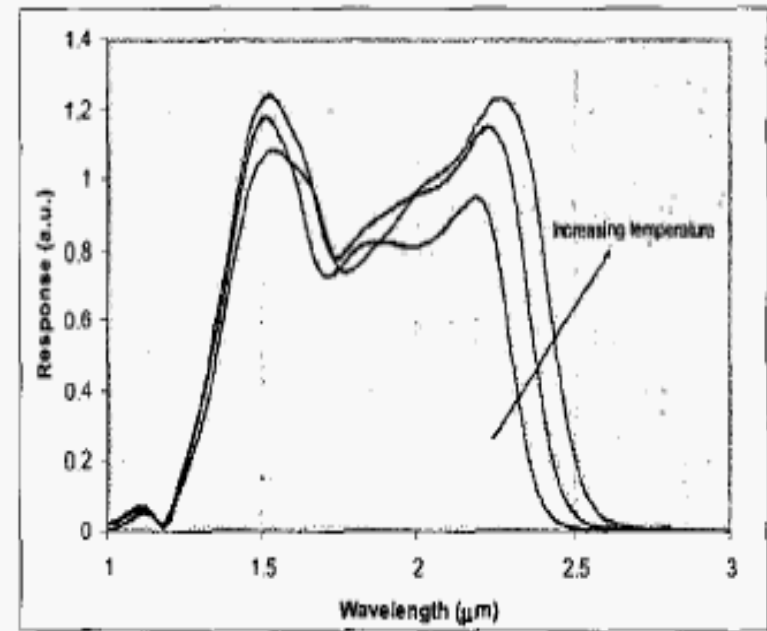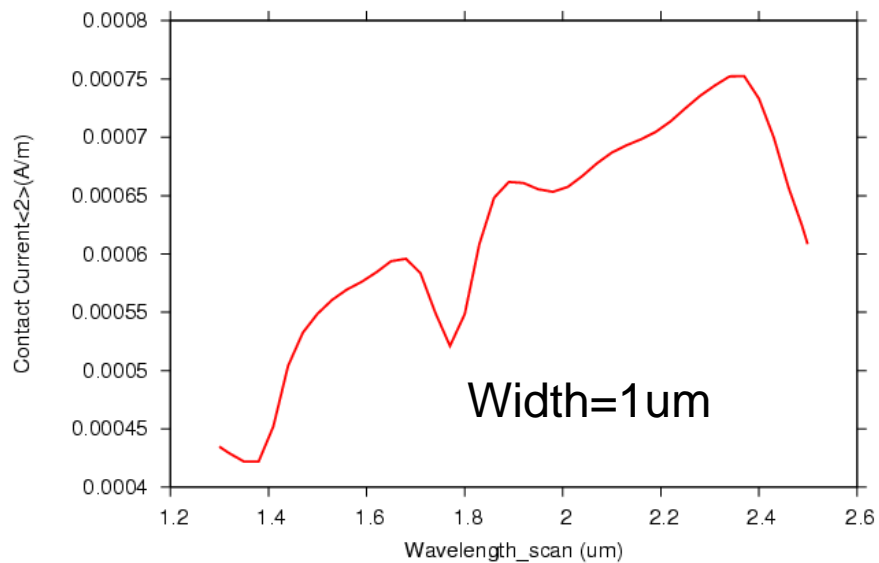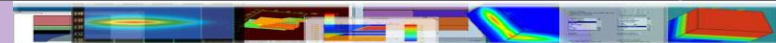
Type-II QWPD: current response

Width=1um

Figure 3. Normal incidence photoresponse at 200K, 250K, and 295K, measured at -2V bias.

Type-II QWPD: external efficiency

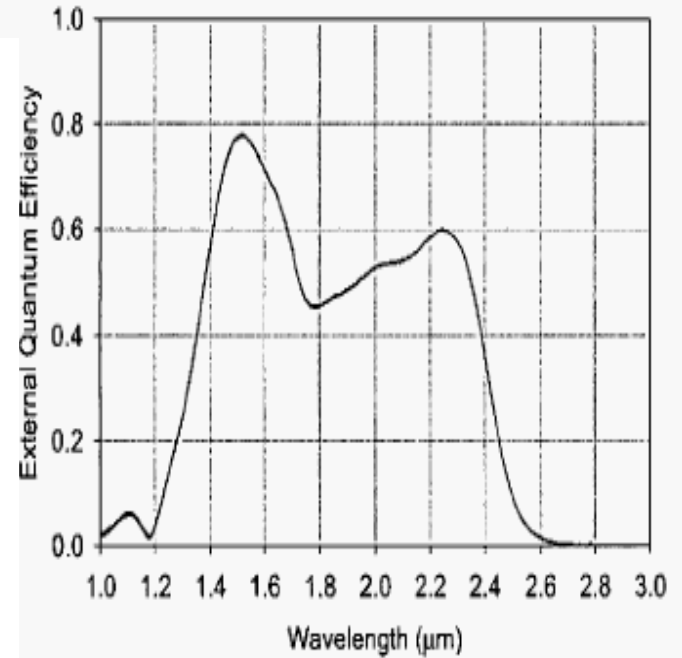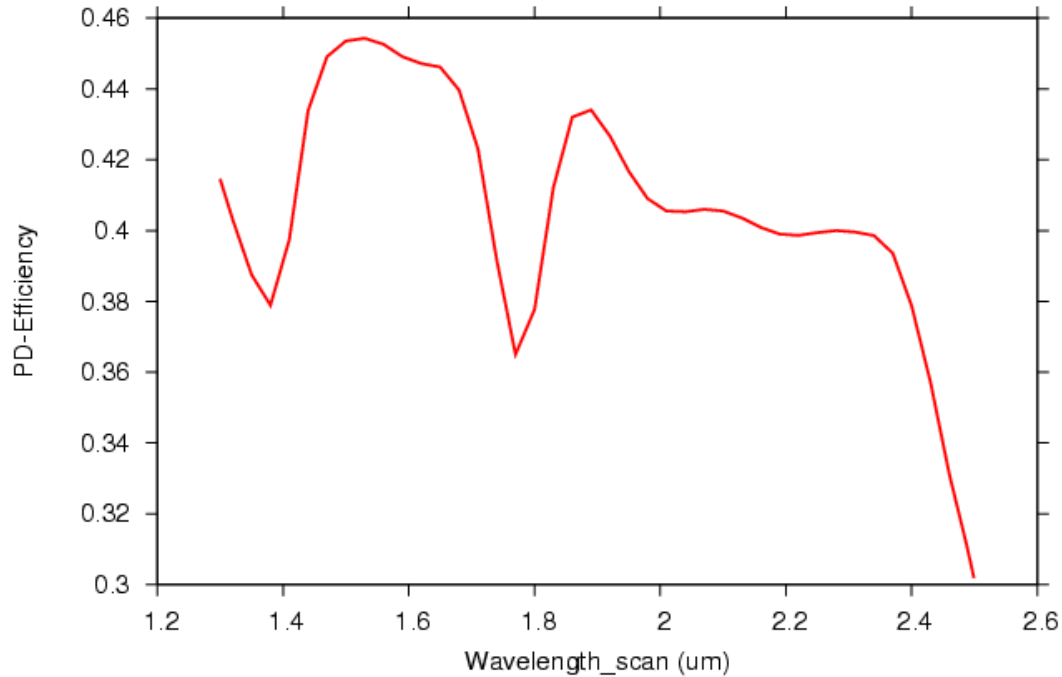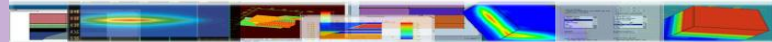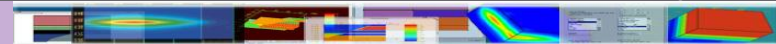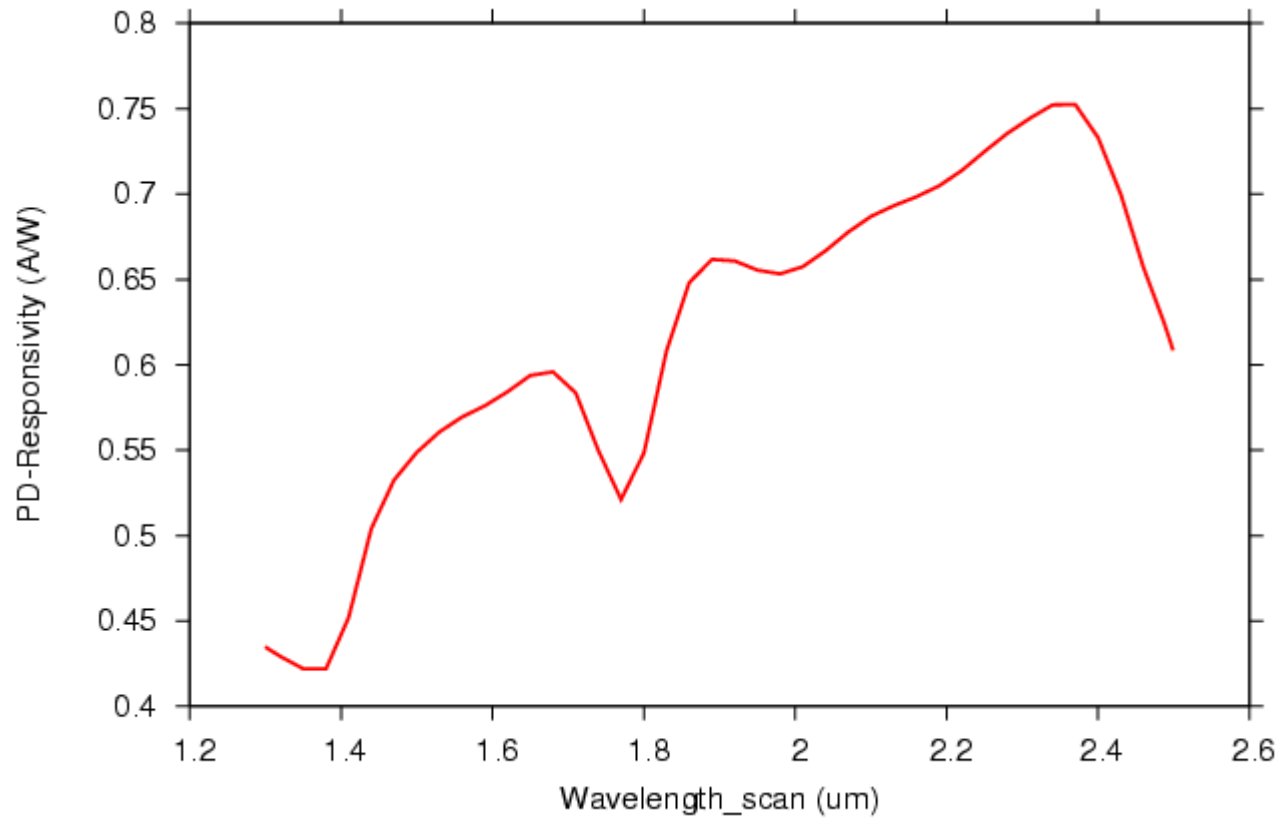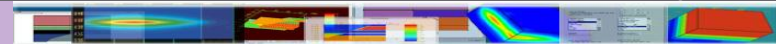Figure 5. Room temperature external quantum efficiency vs. wavelength, at -2V bias

Type-II QWPD: responsivity

Type-II QWPD: light intensity profiles

Wavelength 2.5 um

Wavelength 1.3 um

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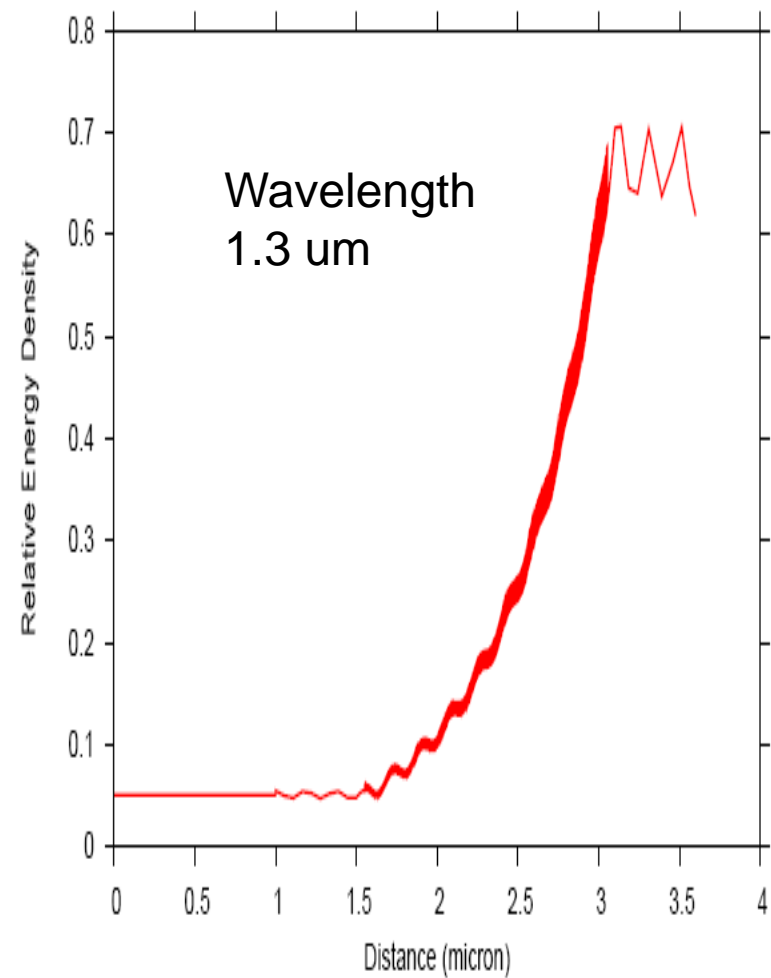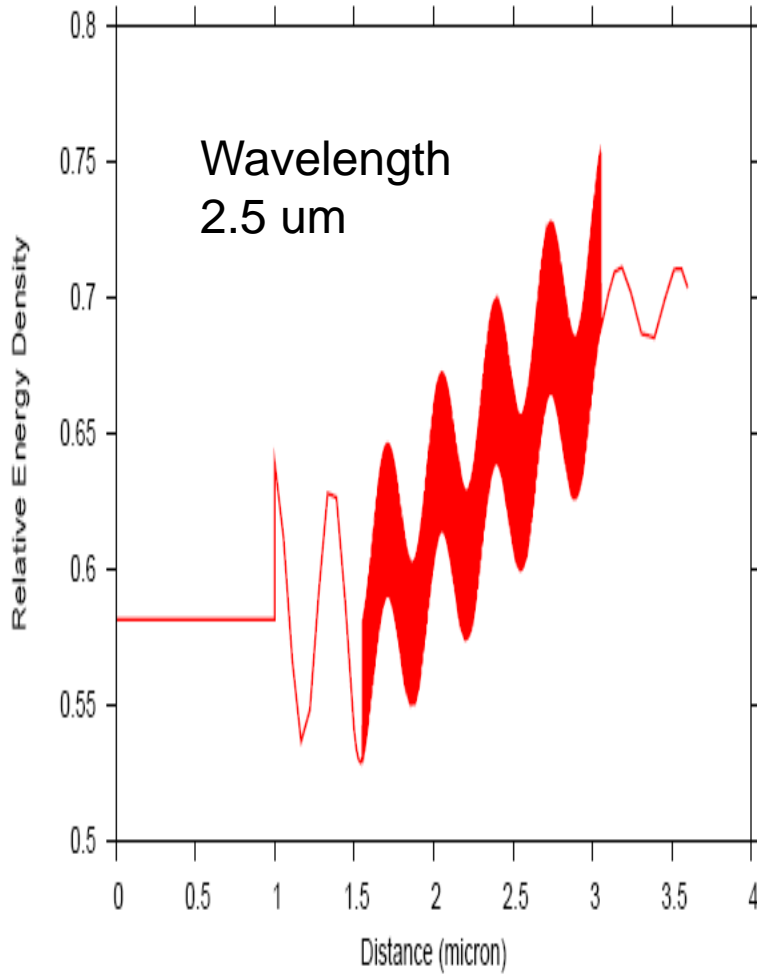
Type-II QWPD: optical generation

2.5 um

1.3 um

MQW div. into 15 blocks
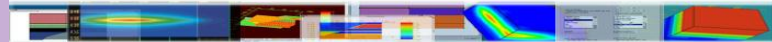
Type-II QWPD: electron concentration
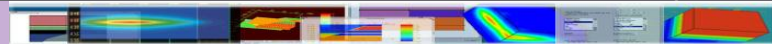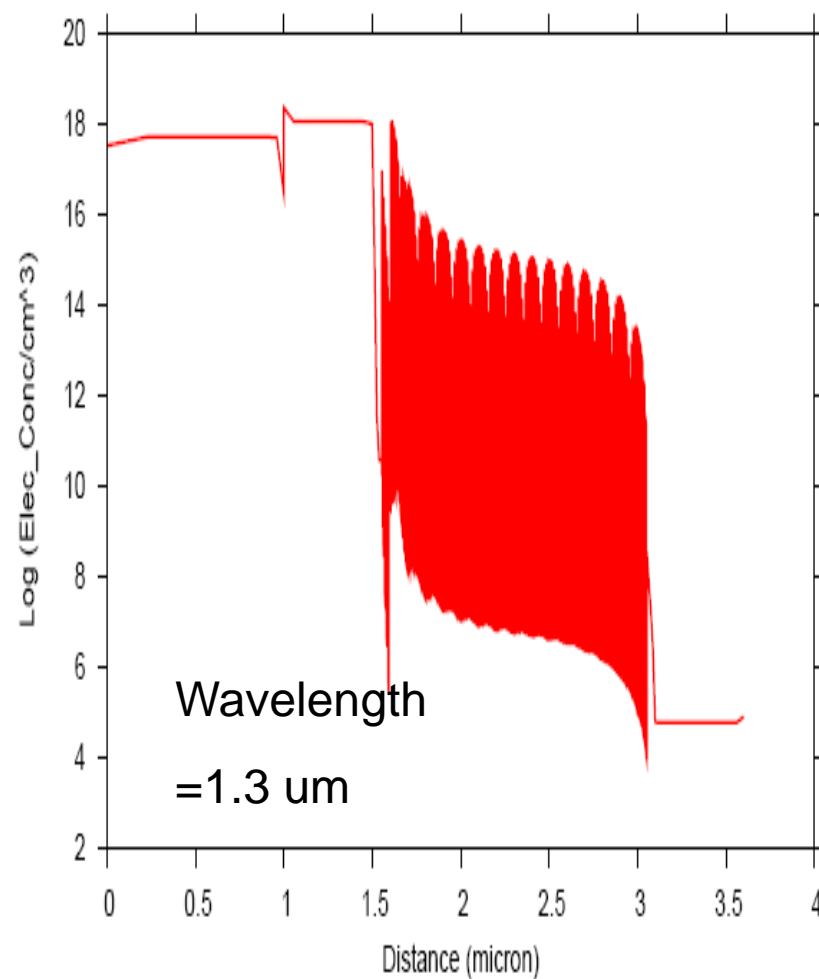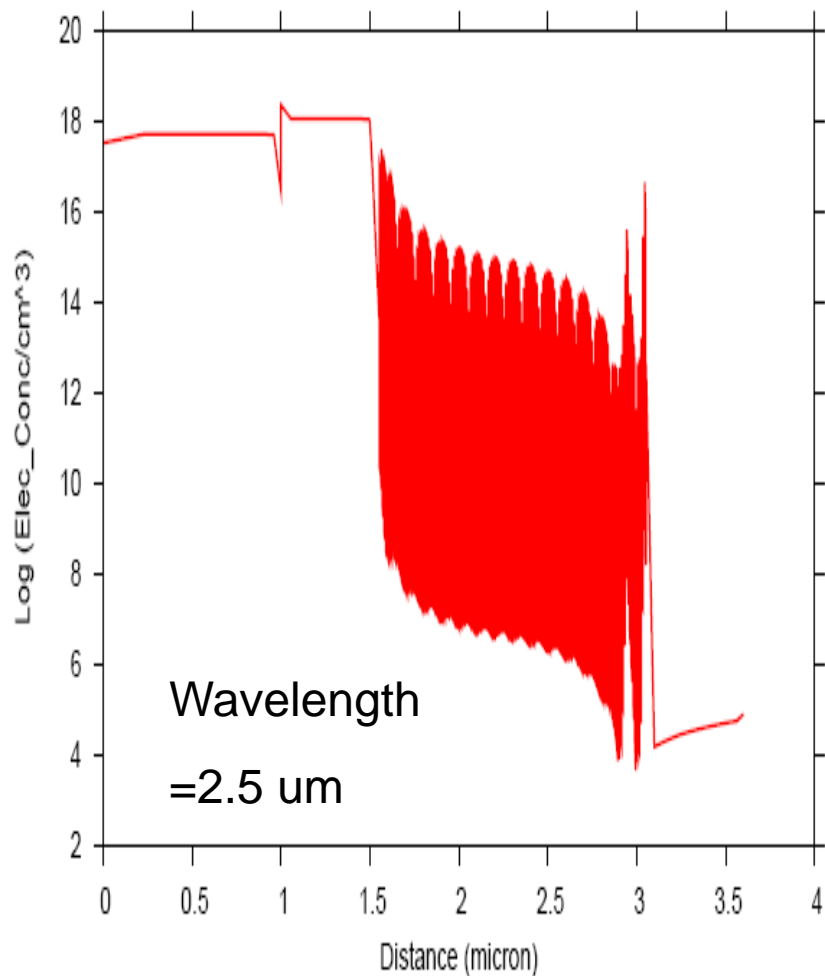
Type-II QWPD: hole concentration

Wavelength
2.5 um

Wavelength
1.3 um

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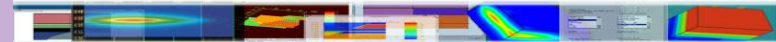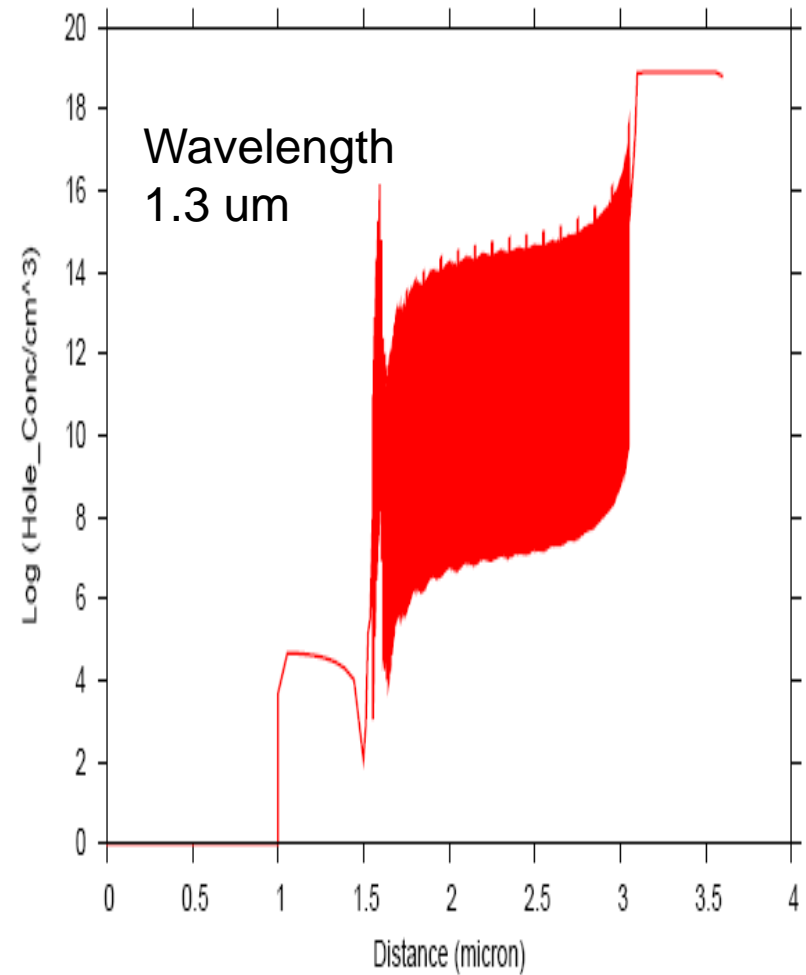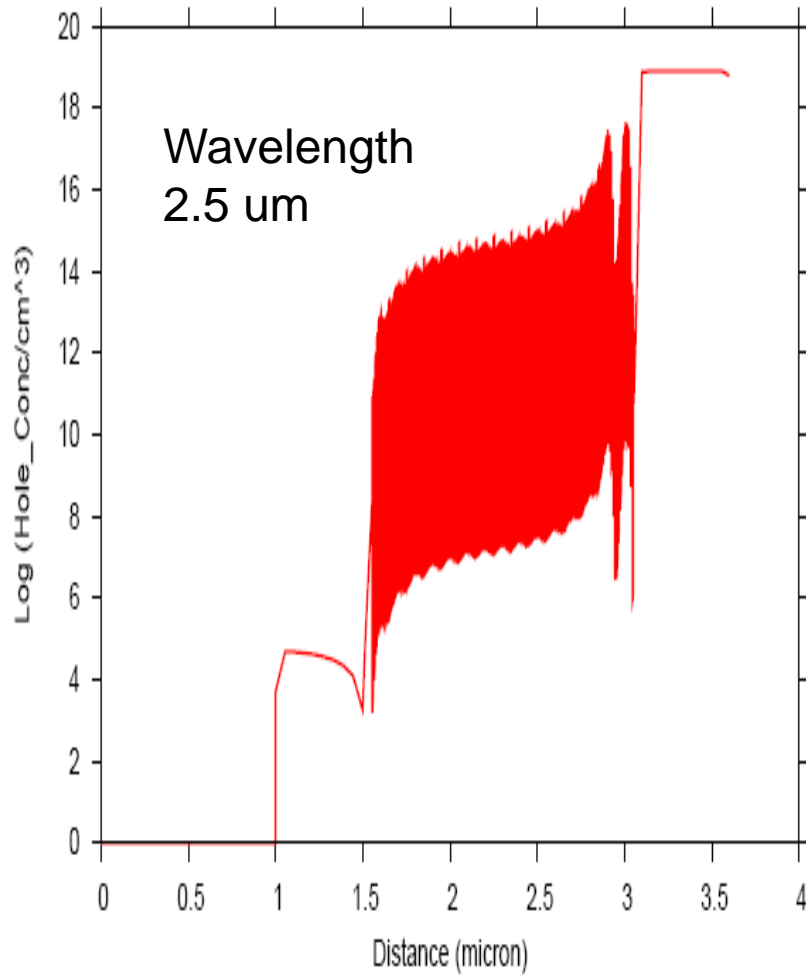
Discussions

PD response as a function of wavelength depends on 3 factors:
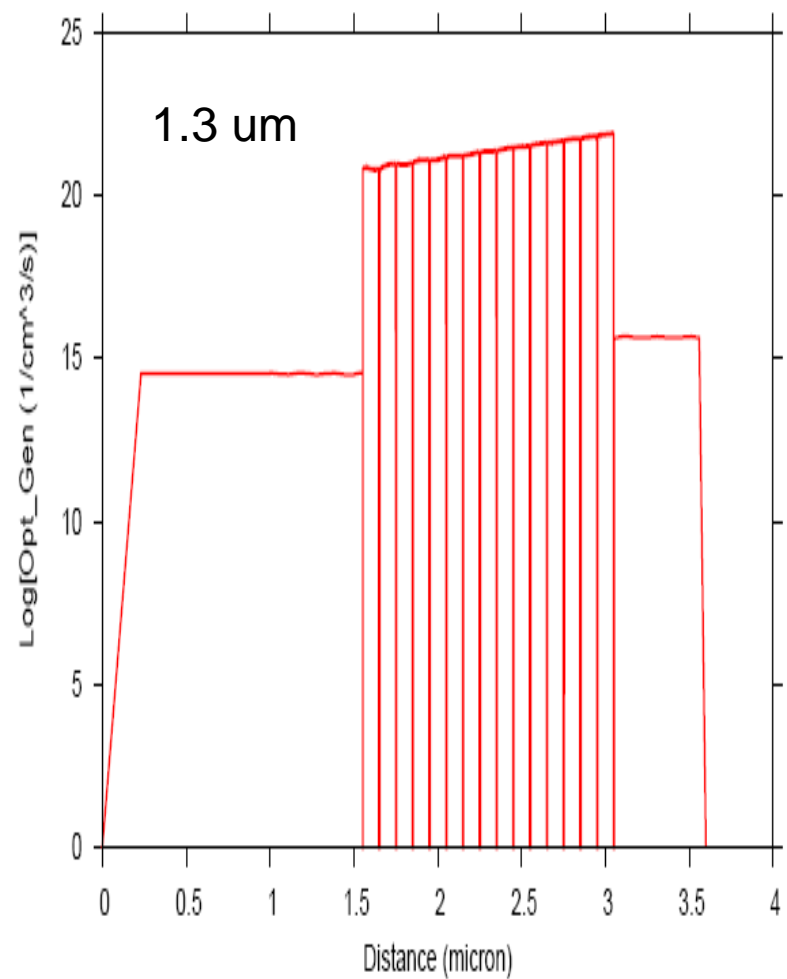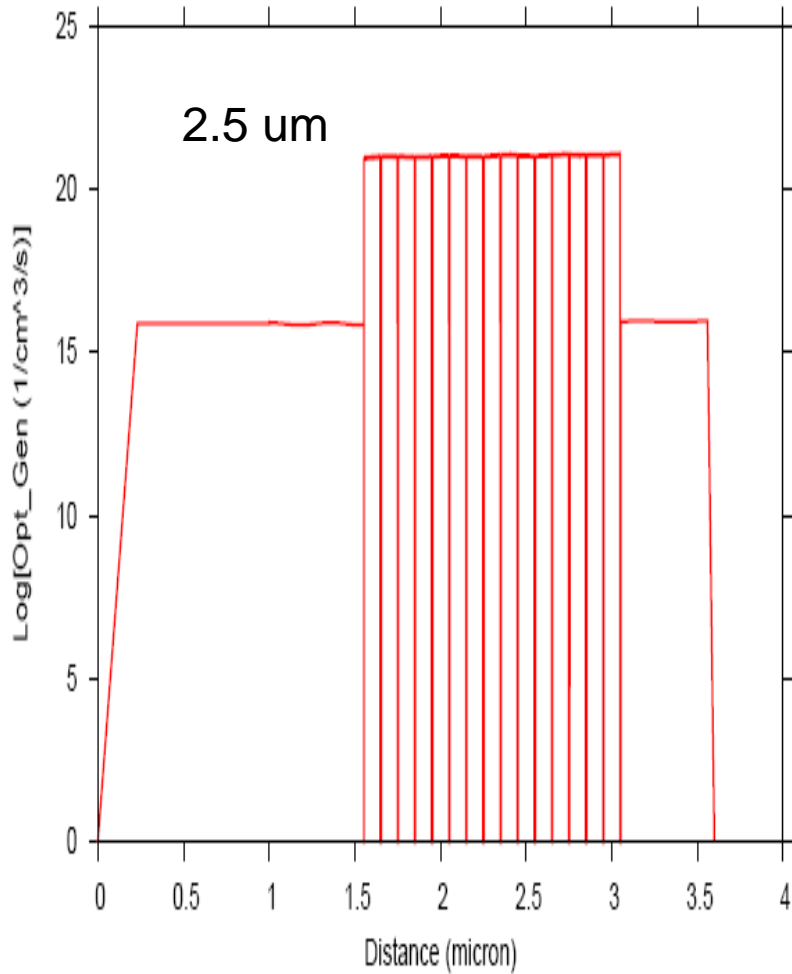
(1) Intrinsic material absorption spectrum ;

(2) Amount and location of absorption for different wavelengths;

(3) Miniband transport and optical generation

Dark current originated from spontaneous recombination which dominates the tunnelling current at dark.

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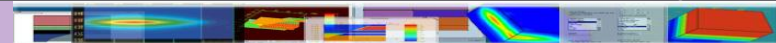
Summary

Crosslight software ready with

(1) Accurate computation of minibands of type-II MQW.

(2) Prediction of material optical absorption spectrum and spontaneous recombination rate as a cause of dark current.

(3) Non-local transport of tunnelling current based on quantum mechanical calculation taking into account local optical generation rates.

Crosslight model demonstrated through a typical type-II MQW PD with results consistent with experimental measurements.
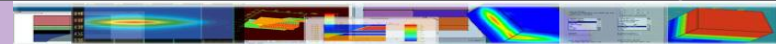
A Glimpse

Crosslight Software

- A leading TCAD provider since 1993

- The world's No.1 TCAD simulator for optics and photonics application

- The world's first commercialized TCAD for Laser Diode

- Customer list extends to hundreds of companies, research institutions and universities world wide.

- Originally licensed from the National Research Council Canada and later from Stanford University

- Complete product portfolio for 2D/3D semiconductor device simulation

- *Café-time Simulator*. Windows based, user friendly graphic user interface makes simulation more enjoyable.

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AlGaAs/AlGaAs
InGaAlP
InGaAlP/GaAs
InGaAs/AlGaAs
InGaAsP
InGaAsP/GaAs
InGaAsP/InGaAlAs-In
InGaAsP/InP
InGaN

Composition

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