Final Project - Mesa structure high speed UTC-PD

ECE530 Introduction to Advanced Electronics & Optoelectronics

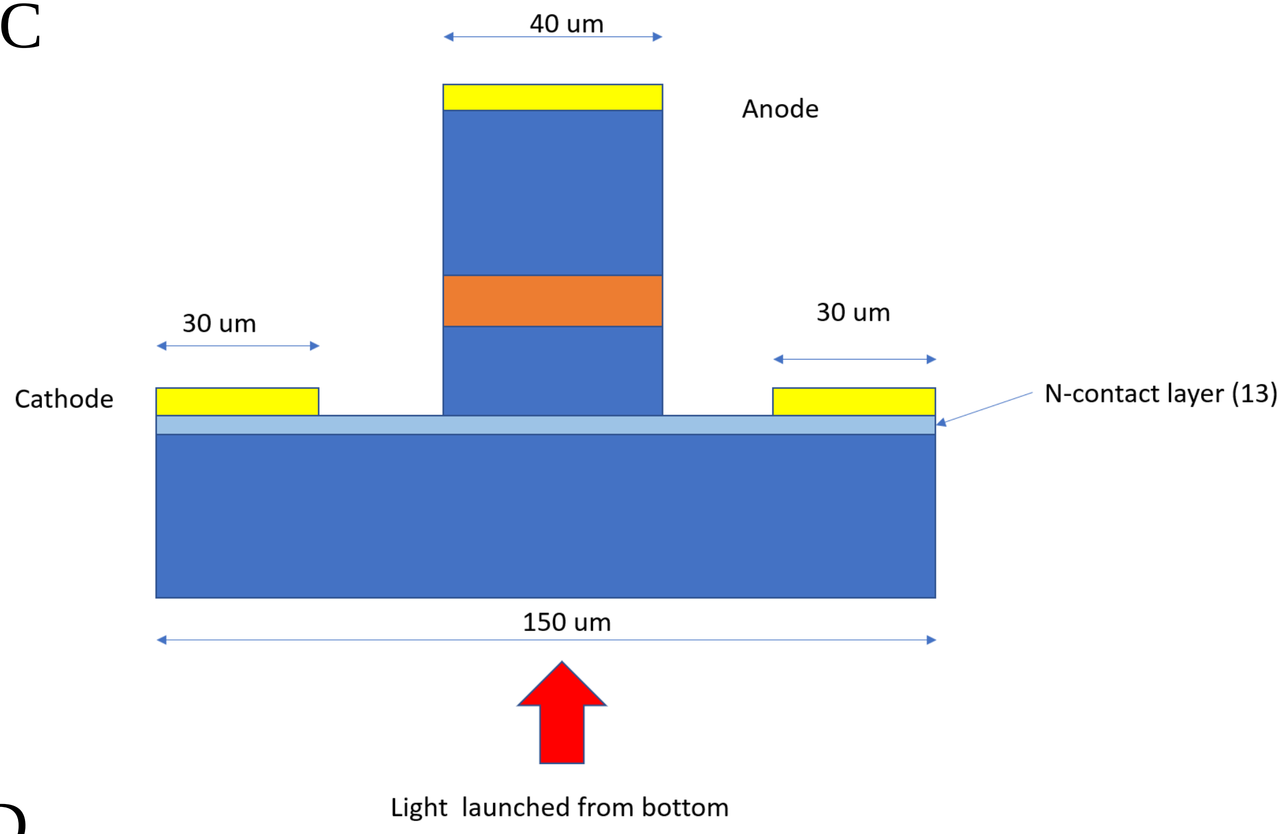
Michael Benker

Project Specification

- Construct an Atlas model for a mesa UTC photodetector.

Please find:

- (1) The x, y composition for lattice matched 1.1Q and 1.4Q.
- (2) Find I-V curve (reverse, forward biased) without light.
- (3) Find the PD impulse response when biased at -3 volt. To mitigate nonlinear effect, use small optical input.
- (4) find the frequency response of the PD.



Structure Layer Definition

Base InP wafer: semi-insulating InP (Fe)

Top down layer structure:

1.	500A	InGaAs	Zn: 2e19	(p-contact)
2.	1000A	InP	Zn: 1.5e18	(e-diffusion block)
3	150A	1.1Q	Zn: 2e18	(band smooth)
4.	150A	1.4Q	Zn: 2e18	(band smooth)
5a.	1000A	InGaAs	Zn: 2e18	(absorber)
5b.	1500A	InGaAs	Zn: 1e18	(absorber)
5c.	1500A	InGaAs	Zn: 5e17	(absorber)
6.	1000A	InGaAs	Si : 1e16	(absorber)
7.	150A	1.4Q	Si : 1e16	(band smooth)
8.	150A	1.1Q	Si : 1e16	(band smooth)
9.	500A	InP	Si: 1e17	(cliff)
10.	6000A	InP	Si : 1e16	(collector)
11.	1000A	InP	Si: 1e18	
12.	9000A	InP	Si: 1e19	
13.	1000A	1.1Q	Si: 1e19	(n-contact)
14.	2500A	InP	Si: 1e19	
15.	SI-substrate (semi-insulating)	InP	Fe	

Compositions (x,y):

$In_xGa_{1-x}As$ (x = 0.532) $In_{0.532}Ga_{0.468}As$

1.4Q
Lattice matchd (to InP) InGaAsP with bandgap corresonding to 1.4 micron photon wavelength

1.1Q
Lattice matchd (to InP) InGaAsP with bandgap corresonding to 1.1 micron photon wavelength

(1) The x, y composition for lattice matched 1.1Q and 1.4Q

Lattice matched (to InP) InGaAsP with bandgap corresponding to photon wavelength

- $E_g = \hbar c/\lambda = (4.135 * 10^{-15}\ eV * s) * (3 * 10^8 \frac{m}{s})/(\lambda)$
- $E_{gInGaAsP}(y) = 1.35 - 0.775y + 0.149y^2\ (eV)\ (at\ 298K)$
- Lattice-Matched to InP: $x = \frac{0.1894y}{0.4184-0.013y}$

```
%InGaAsP matched to InP as function
%        of wavelength program
%Michael Benker

Wavelength = 1.4e-6; %m
PlanksConstant = 4.135e-15; %eV*s
SpeedofLight = 3e8; %m/s
InGaAsP_Bandgap = PlanksConstant...
    *SpeedofLight/Wavelength %eV
syms yComp
BandgapEquation = 1.35-0.775*yComp ...
    +0.1498*(yComp)^2 == InGaAsP_Bandgap;
y = solve(BandgapEquation,yComp);
y = double(y(1,1))
x = 0.1894*y/(0.4184-0.013*y)
```

1.4Q:

1.4 micron photon wavelength

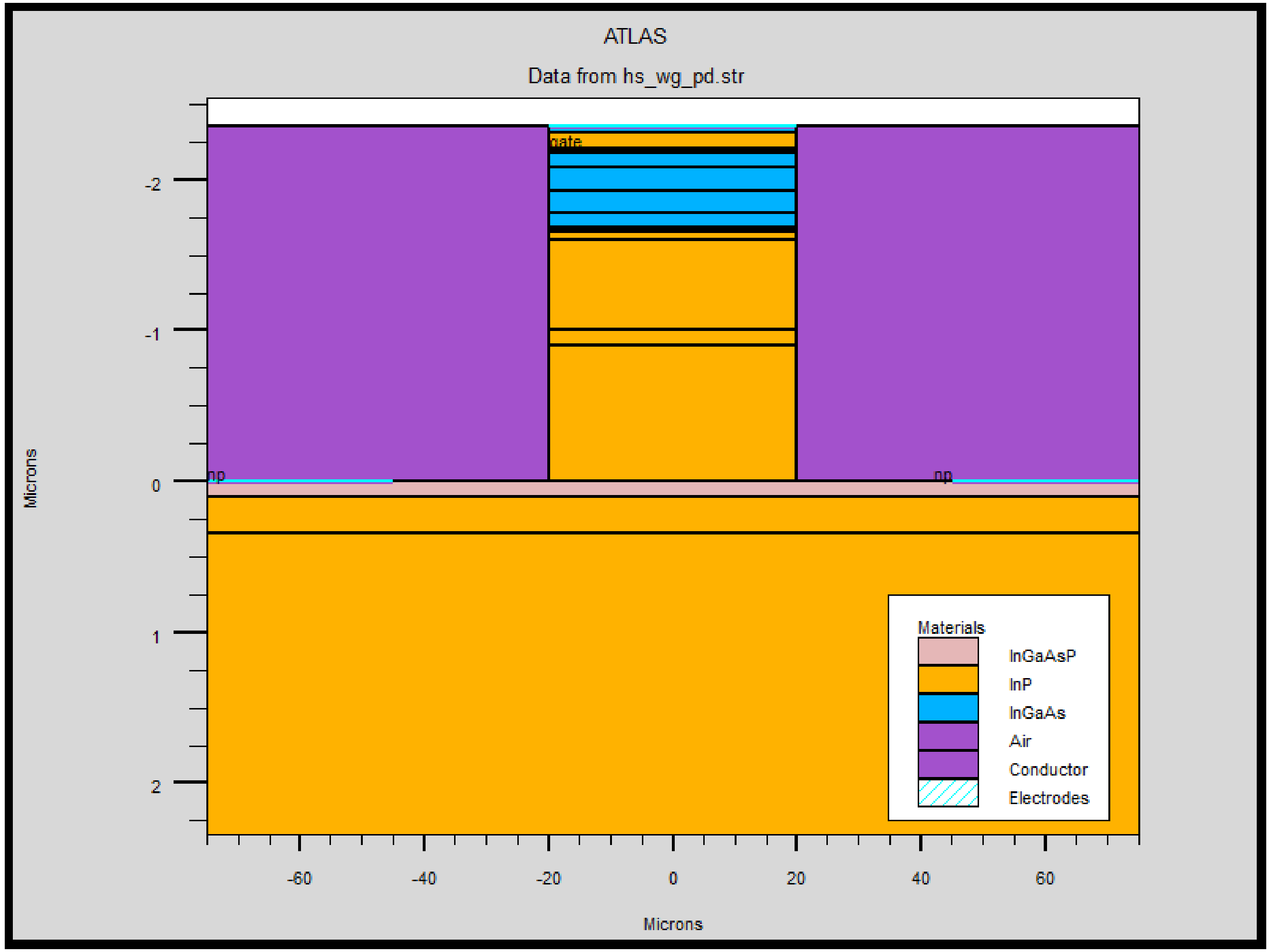
```
InGaAsP_Bandgap =

    0.8861


y =

    0.6909


x =

    0.3196
```

1.1Q:

1.1 micron photon wavelength

```
InGaAsP_Bandgap =

    1.1277


y =

    0.3048


x =

    0.1393
```

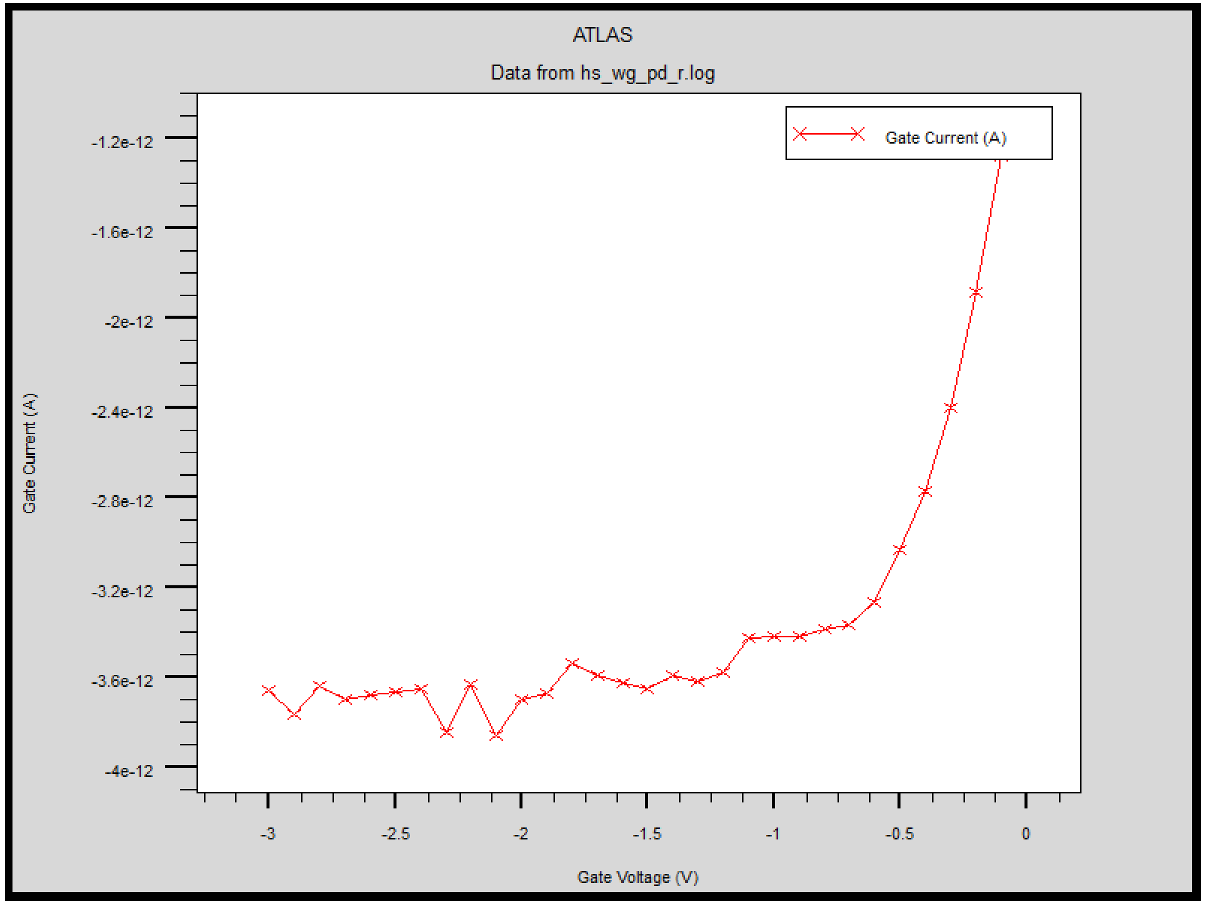
Structure in ATLAS



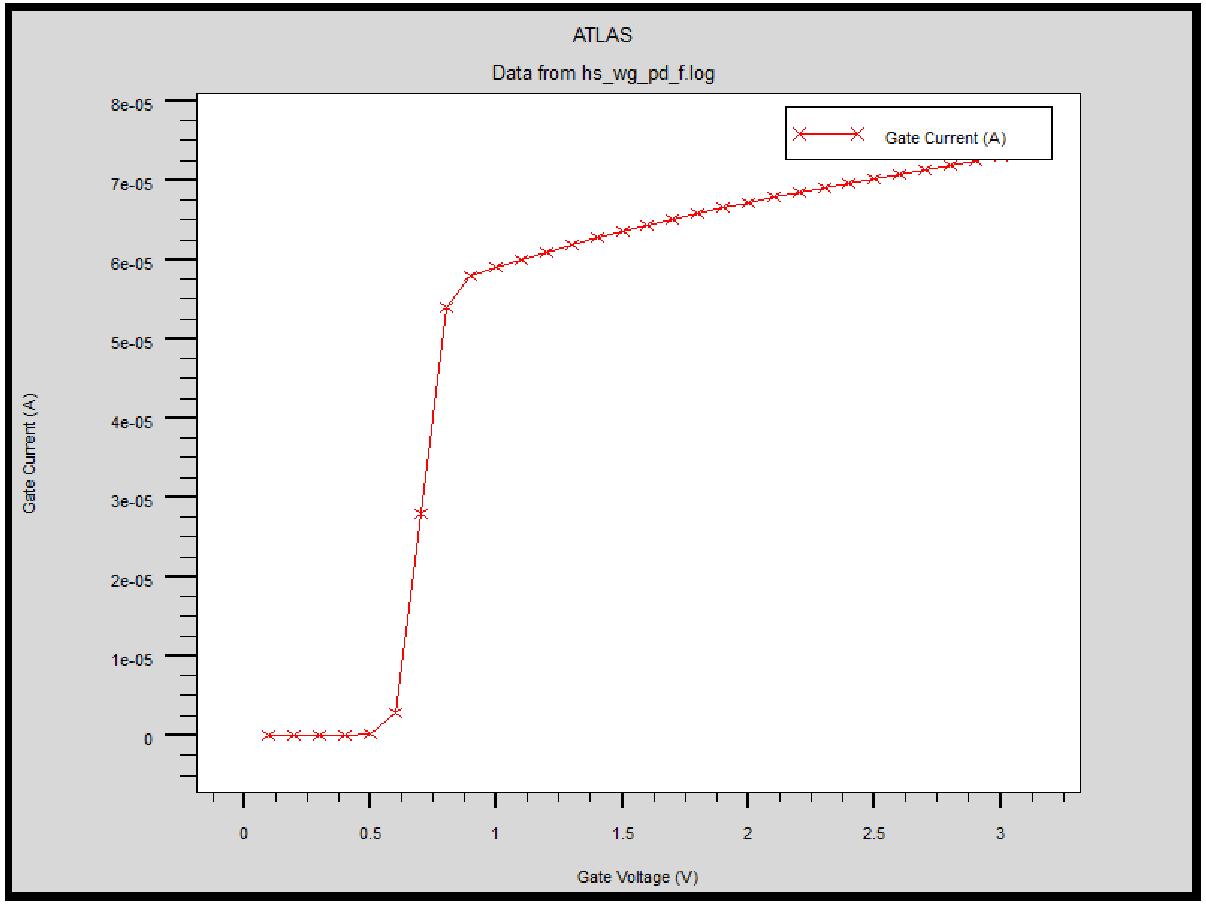

```
mesh auto
x.m l=-75 Spac=3
x.m l=-45 Spac=3
x.m l=-20 Spac=2
x.m l=20 Spac=2
x.m l=45 Spac=3
x.m l=75 Spac =3

# n-contact region to substrate
region bottom  thick = 0.1  material =  InGaAsP NY = 4   x.comp=0.1393  y.comp = 0.3048 donor = 1e19
region bottom  thick = 0.25  material =  InP NY = 4  donor = 1e19
region bottom  thick = 2.0  material =  InP NY = 4

#above n-contact region bottom-up
region top      thick = 0.9  material =  InP  NY = 8 donor = 1e19
region top      thick = 0.1  material =  InP  NY = 8 donor = 1e18
region top      thick = 0.6  material =  InP  NY = 8 donor = 1e16
region top      thick = 0.05  material =  InP  NY = 8 donor = 1e17

#band smooth
region top      thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.1393  y.comp = 0.3048 donor = 1e16
region top      thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.3196 y.comp = 0.6909 donor = 1e16

#absorber
region top  thick = 0.1   mat = InGaAs  NY = 8 x.comp=0.532 donor = 1e16
region top  thick = 0.15  mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 5e17
region top  thick = 0.15  mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 1e18
region top  thick = 0.1   mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 2e18
region top  thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.3196 y.comp = 0.6909 acceptor = 2e18
region top  thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.1393  y.comp = 0.3048 acceptor = 2e18
region top  thick = 0.1  material =  InP  NY = 8 acceptor = 1.5e18
region top  thick = 0.05  mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 2e19

#etch
region  mat = air  x.min=20 x.max = 75 y.max = 0.0 NY = 3
region  mat = air  x.min = -75 x.max = -20 y.max = 0.0 NY = 3

#electrode
electrode name=gate x.min = -20 x.max =20 top
electrode name=np x.min=45 x.max=75 y.max = 0 y.min = 0
electrode name=np x.min=-75 x.max=-45 y.max = 0 y.min = 0
```

(2) Find I-V curve (reverse, forward biased) without light

Reverse Bias

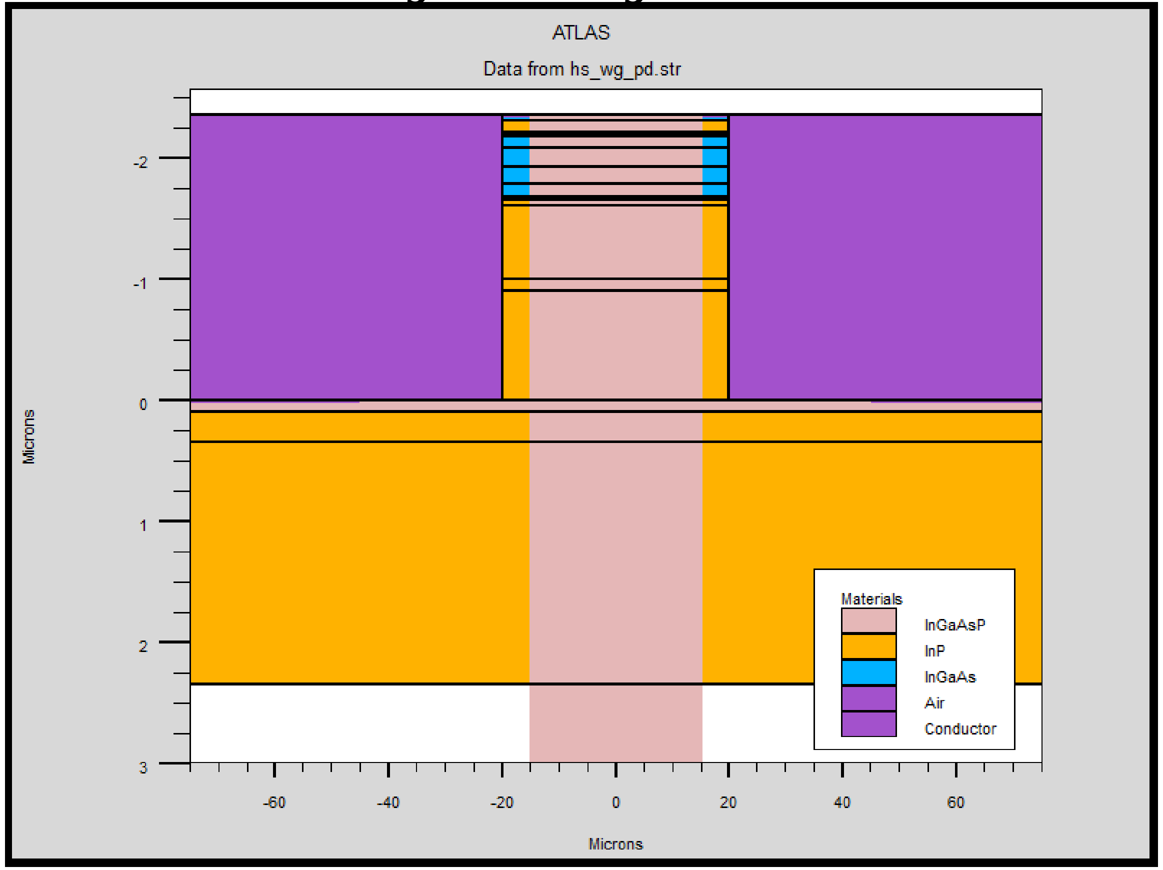


Forward Bias

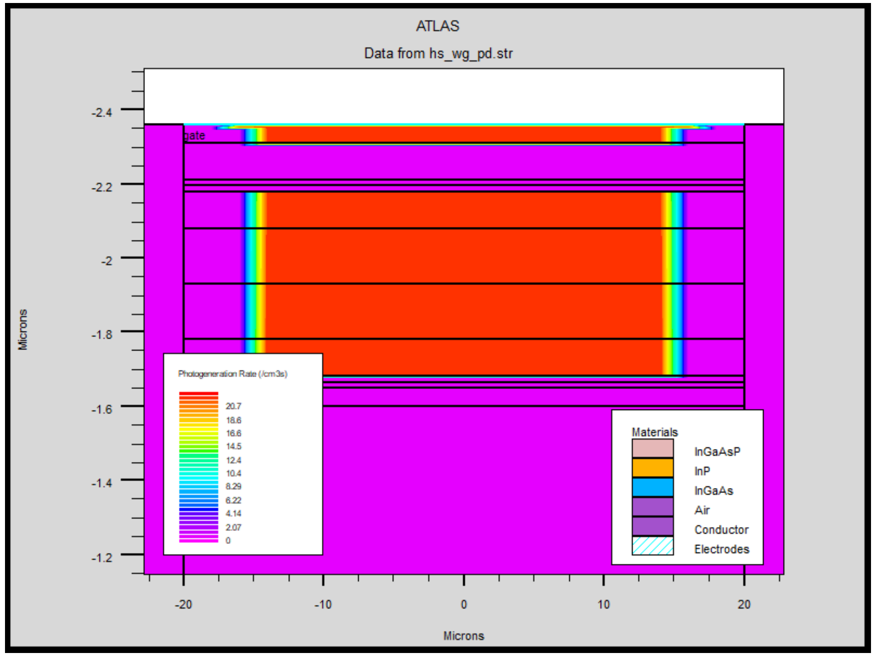


Simulating Beam

Light entering bottom



Photogeneration Rate



Photogeneration Rate: number of electrons generated in the device due to absorption of photons. ✓

Beam ATLAS Code (one intensity level):

- beam num=1 x.origin=0 y.origin=3 angle=270 wavelength=1.550 min.window=-15 max.window=15
- ……
- solve vgate=-3.0
- solve b1=0.1 outf=sol_hswgpd.str master onefile

Light Impulse in ATLAS

Light Impulse L[t] = u[t] – u[t-T]

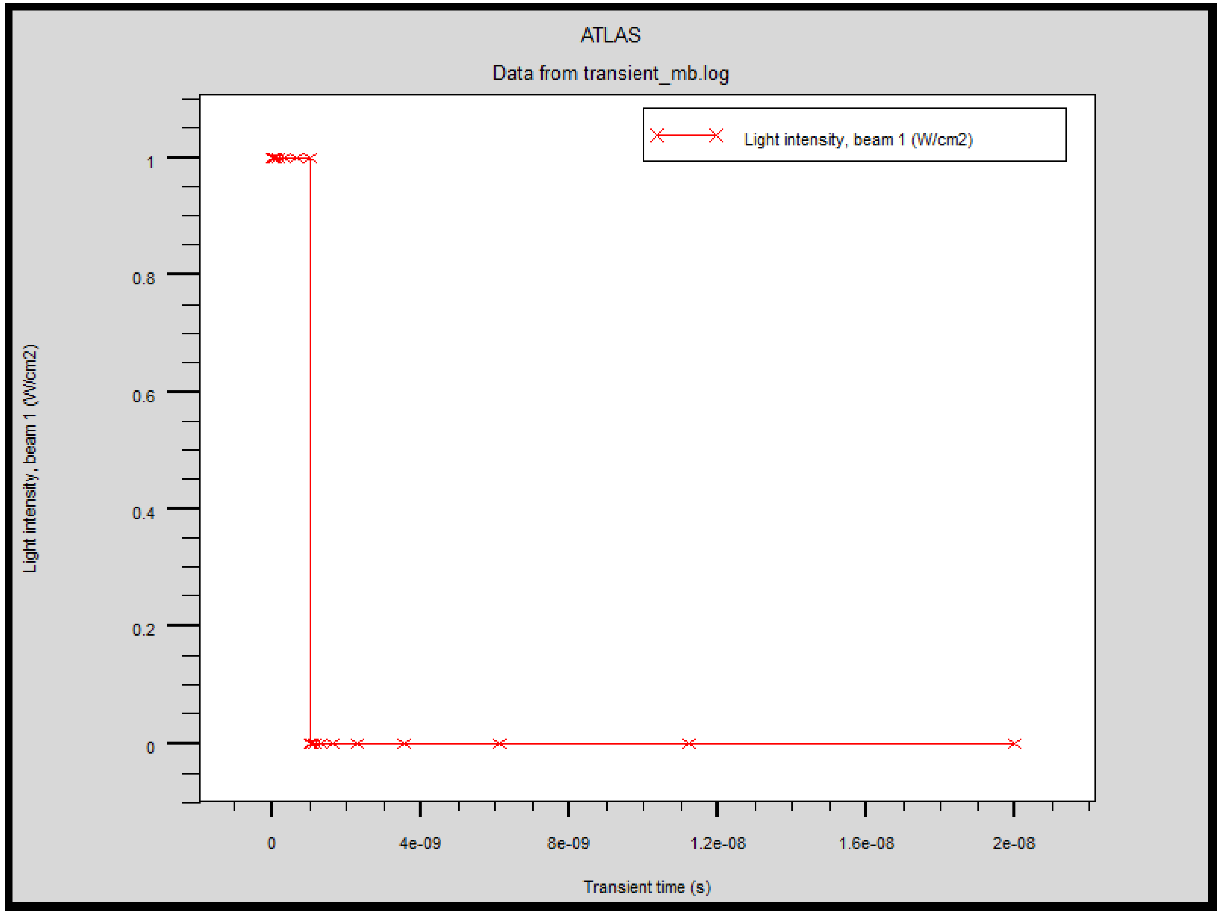
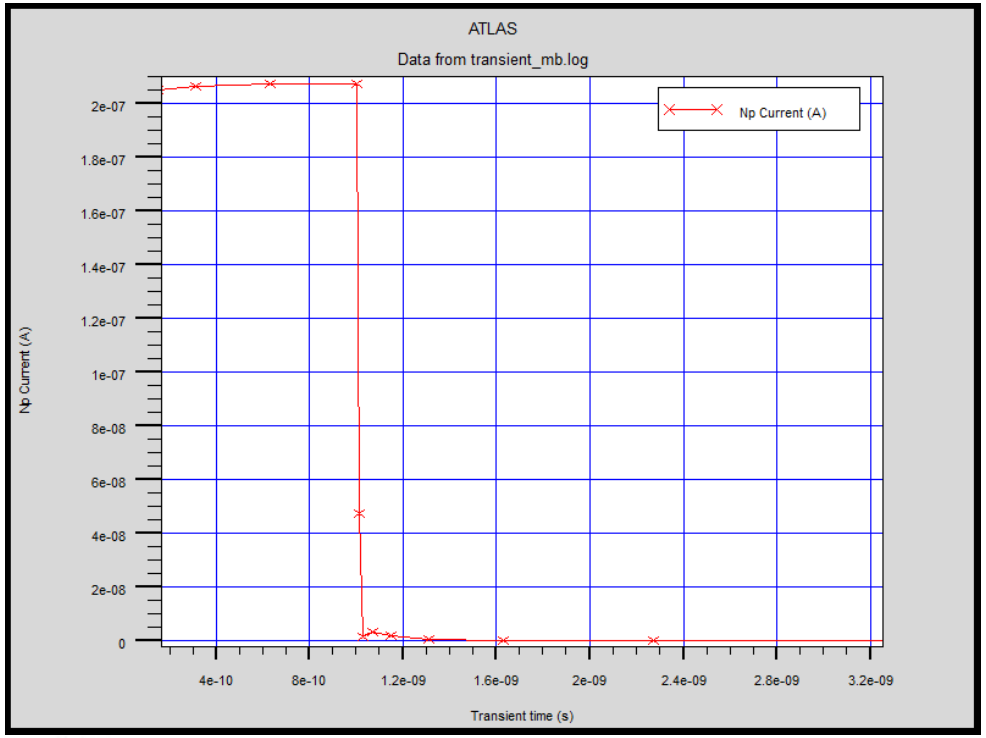
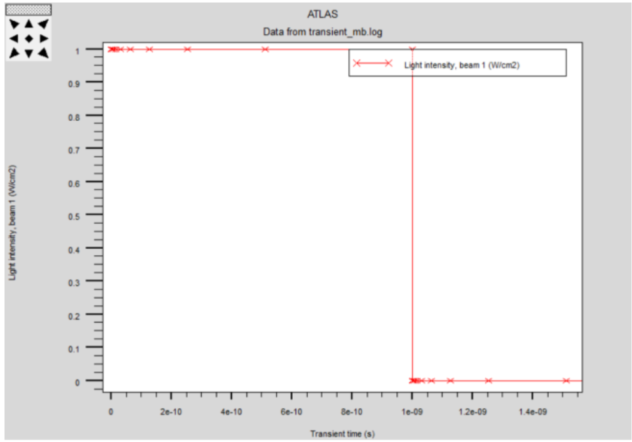


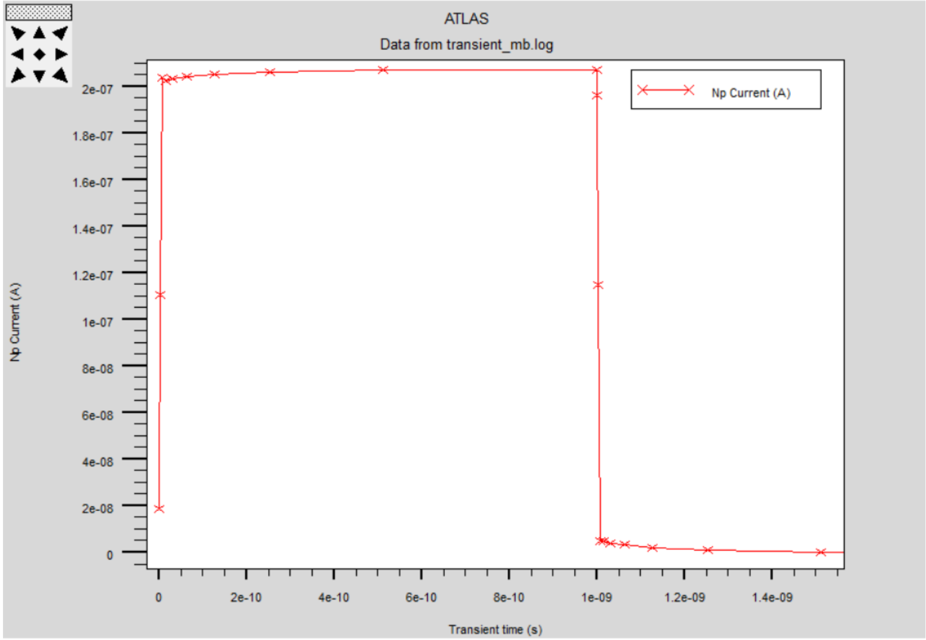
Photo-current Response

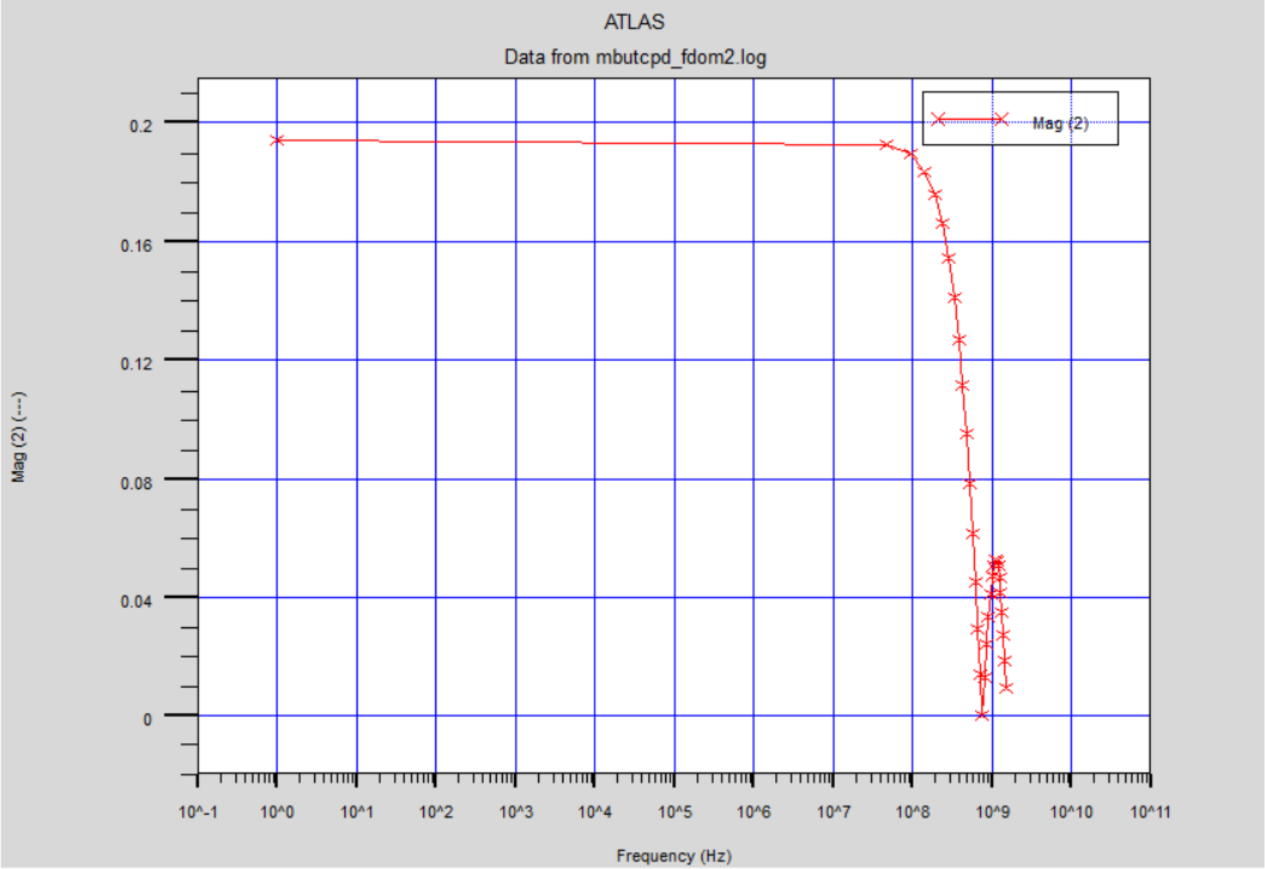



```
solve vgate=-3.0

LOG off

LOG outf=transient_mb.log
SOLVE B1=1.0 RAMPTIME=1E-9 TSTOP=1E-9 TSTEP=1E-11
SOLVE B1=0.0 RAMPTIME=1E-9 TSTOP=20E-9 TSTEP=1E-11

tonyplot transient_mb.log
```

Frequency Response: Using ATLAS



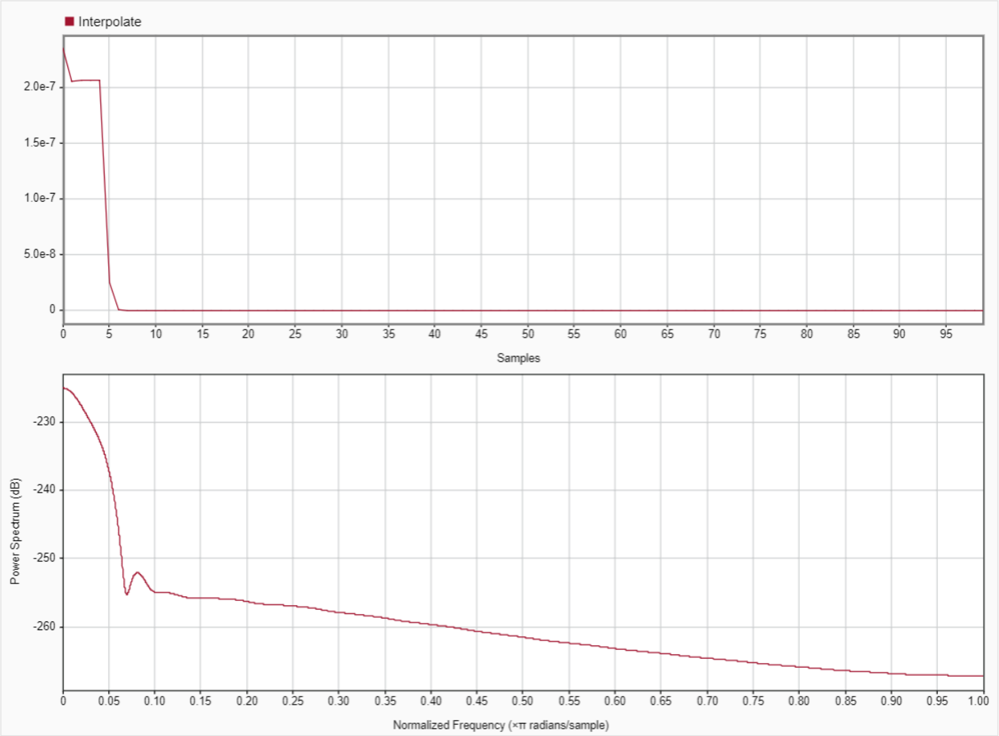


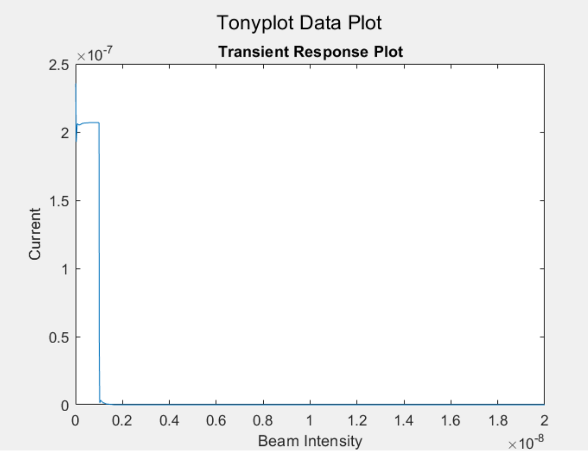


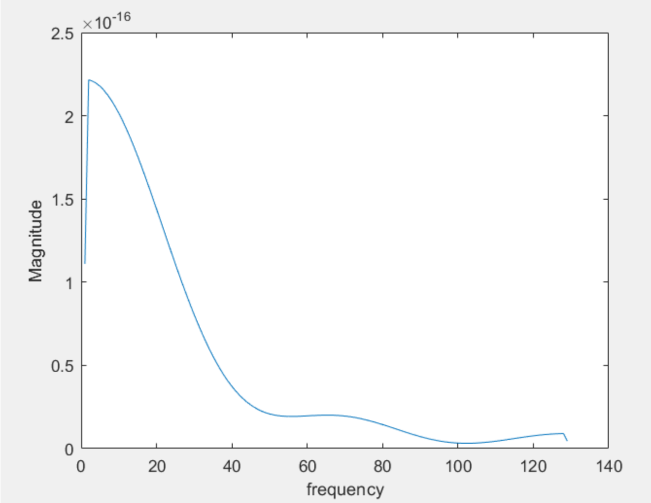

```
log outf=mbutcpd_fdom2.log
FOURIER INFILE=transient_mb.log OUTFILE=mbutcpd_fdom2.log T.START=0  T.STOP=20E-9  INTERPOLATE
tonyplot mbutcpd_fdom2.log
```

Frequency Response: Method #2

MATLAB file import, plot








```
%Michael Benker
%ECE530 Final Project
%This program imports data exported from a Tonyplot and calculates the
%frequency response.
clc; clear all; close all; clf;

TonyPlotData = importdata('exporttransientresponse1.dat'); %exported data file from Tonyplot

TransientTime = TonyPlotData.data(4:21,1);
PhotoCurrent = TonyPlotData.data(4:21,2);
NewTimeAxis = linspace(TransientTime(1),TransientTime(18),100);
Interpolate = interp1(TransientTime, PhotoCurrent, NewTimeAxis);
```

Conclusions

1. The x and y composition for InGaAsP matched to InP were calculated using formulas and a short MATLAB program. ✓
2. The UTC Photodetector structure was designed and simulated in ATLAS. ✓
3. An I-V curve for forward and reverse bias was simulated for the structure in ATLAS. ✓
4. A light beam is simulated into the structure in ATLAS and the photo-current generation is simulated to occur in the InGaAs layers. ✓
5. A light impulse is simulated using step functions in ATLAS and the current response from the light pulse is observed in ATLAS at -3V bias. ✓
6. Using the fourier command in ATLAS, the frequency response of the impulse is plotted in ATLAS. Simulations were also run in MATLAB to compare results. ✓

MATLAB Code(s)

```
%InGaAsP matched to InP as function
%       of wavelength program
%Michael Benker

Wavelength = 1.1e-6; %m
PlanksConstant = 4.135e-15; %eV*s
SpeedofLight = 3e8; %m/s
InGaAsP_Bandgap = PlanksConstant...
    *SpeedofLight/Wavelength %eV
syms yComp
BandgapEquation = 1.35-0.775*yComp ...
    +0.1498*(yComp)^2 == InGaAsP_Bandgap;
y = solve(BandgapEquation,yComp);
y = double(y(1,1))
x = 0.1894*y/(0.4184-0.013*y)
```

```
%Michael Benker
%ECE530 Final Project
%This program imports data exported from a Tonyplot and calculates the
%frequency response.
clc; clear all; close all; clf;

X = importdata('transientin1.dat'); %exported data file from Tonyplot
Y =
TransientTime = TonyPlotData.data(4:21,1);
PhotoCurrent = TonyPlotData.data(4:21,2);
NewTimeAxis = linspace(TransientTime(1),TransientTime(18),100);
Interpolate = interp1(TransientTime, PhotoCurrent, NewTimeAxis);

%Interpolate = zeros(18,2);
%Interpolate(:,1) = TransientTime;
%Interpolate(:,2) = PhotoCurrent;

figure(1) %Plot Tonyplot data
    plot(TransientTime, PhotoCurrent)
    suptitle('Tonyplot Data Plot')
    xlabel('Beam Intensity')
    ylabel('Current')
    title('Transient Response Plot')

freqz(Interpolate)
Fdomain = pwelch(Interpolate);

figure(2)
plot(Fdomain)
xlabel('frequency')
ylabel('Magnitude')
```

ATLAS Code – IV Curves

```
#Michael Benker
#ECE530 Advanced Electronics/Optoelectronics

go atlas

mesh auto
x.m l=-75 Spac=3
x.m l=-45 Spac=3
x.m l=-20 Spac=2
x.m l=20 Spac=2
x.m l=45 Spac=3
x.m l=75 Spac =3

# n-contact region to substrate
region bottom  thick = 0.1  material =  InGaAsP NY = 4 x.comp=0.1393  y.comp = 0.3048 donor = 1e19
region bottom  thick = 0.25  material =  InP NY = 4  donor = 1e19
region bottom  thick = 2.0  material =  InP NY = 4

#above n-contact region bottom-up
region top      thick = 0.9  material =  InP  NY = 8 donor = 1e19
region top      thick = 0.1  material =  InP  NY = 8 donor = 1e18
region top      thick = 0.6  material =  InP  NY = 8 donor = 1e16
region top      thick = 0.05  material =  InP  NY = 8 donor = 1e17

#band smooth
region top      thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.1393  y.comp = 0.3048 donor = 1e16
region top      thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.3196 y.comp = 0.6909 donor = 1e16

#absorber
region top   thick = 0.1    mat = InGaAs  NY = 8 x.comp=0.532 donor = 1e16
region top   thick = 0.15   mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 5e17
region top   thick = 0.15   mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 1e18
region top   thick = 0.1    mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 2e18

region top   thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.3196 y.comp = 0.6909 acceptor = 2e18
region top   thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.1393  y.comp = 0.3048 acceptor = 2e18

region top   thick = 0.1  material =  InP  NY = 8 acceptor = 1.5e18
region top   thick = 0.05   mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 2e19

#etch

region  mat = air  x.min=20 x.max = 75 y.max = 0.0 NY = 3
region  mat = air  x.min = -75 x.max = -20 y.max = 0.0 NY = 3

#electrode

electrode name=gate x.min = -20 x.max =20 top
electrode name=np x.min=45 x.max=75 y.max = 0 y.min = 0
electrode name=np x.min=-75 x.max=-45 y.max = 0 y.min = 0

contact name=gate resistance = 0.1

#interface y.min=-1.9 y.max=-1.4 x.min=-1 x.max=1 thermionic=true tunnel=true s.s=true
#Materials

material material=InGaAsP taun0=20.e-9 taup0=33e-9 \
  align=0.4 real.index=3.4 imag.index=0

material material=InGaAs taun0=0.7e-9 taup0=33e-9 \
 real.index=3.43 imag.index=0.2

material  material=InP   taun0=2e-9 taup0=33e-9 \
 align=0.4 real.index=3.17 imag.index=0

#model

mobility material = InP mun=4917.0 mup=150.0 vsatn =  2.6e7 vsatp = 0.66e7 ecritn=11e3 ecritp=4e3 gamman=4 gammap=1
mobility material = InGaAs  mun=11599.0 mup=331.0 vsatn = 2.5e7 vsatp=0.5e7 ecritn=3e3 ecritp=4e3 gamman=4 gammap=1
mobility material = InGaAsP mun=4600.0 mup=150.0  vsatn = 2.68e7 vsatp=0.6e7 ecritn=6e3 ecritp=4e3 gamman=4 gammap=1

models fldmob srh optr fermidirac conmob print EVSATMOD=1

#solving

solve  init outf = sol_hswgpd.str
load inf = sol_hswgpd.str

LOG outf=hs_wg_pd_f.log
solve vgate=0.1 vstep=0.1 vfinal=3 name="gate"
tonyplot hs_wg_pd_f.log

log off

solve  init
#beam     num=1 x.origin=5.0 y.origin=0.0 angle=-90.0 wavelengtht=0.550 rays=100 sigma=1.0 gaussian periodic
outf = sol_hswgpd.str
LOG outf=hs_wg_pd_r.log

solve vgate=-0.1 vstep=-0.1 vfinal=-3 name="gate"

tonyplot hs_wg_pd_r.log

log off

output band.param photogen opt.intens con.band val.band e.mobility h.mobility band.param photogen opt.intens recomb u.srh u.aug u.rad flowlines

save outf=hs_wg_pd.str

tonyplot hs_wg_pd.str

#tonyplot sol_hswgpd.str

quit
```

ATLAS Code – Beam

```
#Michael Benker
#ECE530 Advanced Electronics/Optoelectronics

go atlas

mesh auto
x.m l=-75 Spac=3
x.m l=-45 Spac=3
x.m l=-20 Spac=2
x.m l=20 Spac=2
x.m l=45 Spac=3
x.m l=75 Spac =3

# n-contact region to substrate
region bottom  thick = 0.1  material =  InGaAsP NY = 4 x.comp=0.1393  y.comp = 0.3048 donor = 1e19
region bottom  thick = 0.25  material =  InP NY = 4  donor = 1e19
region bottom  thick = 2.0  material =  InP NY = 4

#above n-contact region bottom-up
region top      thick = 0.9  material =  InP  NY = 8 donor = 1e19

region top      thick = 0.1  material =  InP  NY = 8 donor = 1e18
region top      thick = 0.6  material =  InP  NY = 8 donor = 1e16
region top      thick = 0.05  material =  InP  NY = 8 donor = 1e17

#band smooth
region top      thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.1393  y.comp = 0.3048 donor = 1e16
region top      thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.3196 y.comp = 0.6909 donor = 1e16

#absorber
region top   thick = 0.1    mat = InGaAs  NY = 8 x.comp=0.532 donor = 1e16
region top   thick = 0.15   mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 5e17
region top   thick = 0.15   mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 1e18
region top   thick = 0.1    mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 2e18

region top   thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.3196 y.comp = 0.6909 acceptor = 2e18
region top   thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.1393  y.comp = 0.3048 acceptor = 2e18

region top   thick = 0.1  material =  InP  NY = 8 acceptor = 1.5e18
region top   thick = 0.05   mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 2e19

#etch
region  mat = air  x.min=20 x.max = 75 y.max = 0.0 NY = 3
region  mat = air  x.min = -75 x.max = -20 y.max = 0.0 NY = 3

#electrode

electrode name=gate x.min = -20 x.max =20 top
electrode name=np x.min=45 x.max=75 y.max = 0 y.min = 0
electrode name=np x.min=-75 x.max=-45 y.max = 0 y.min = 0

contact name=gate resistance = 0.1

#interface y.min=-1.9 y.max=-1.4 x.min=-1 x.max=1 thermionic=true tunnel=true s.s=true
#Materials

material material=InGaAsP taun0=20.e-9 taup0=33e-9 \
  align=0.4 real.index=3.4 imag.index=0
material material=InGaAs taun0=0.7e-9 taup0=33e-9 \
 real.index=3.43 imag.index=0.2

material  material=InP   taun0=2e-9 taup0=33e-9 \
 align=0.4 real.index=3.17 imag.index=0

#model

mobility material = InP mun=4917.0 mup=150.0 vsatn =  2.6e7 vsatp = 0.66e7 ecritn=11e3 ecritp=4e3 gamman=4 gammap=1
mobility material = InGaAs  mun=11599.0 mup=331.0 vsatn = 2.5e7 vsatp=0.5e7 ecritn=3e3 ecritp=4e3 gamman=4 gammap=1
mobility material = InGaAsP mun=4600.0 mup=150.0  vsatn = 2.68e7 vsatp=0.6e7 ecritn=6e3 ecritp=4e3 gamman=4 gammap=1

models fldmob srh optr fermidirac conmob print EVSATMOD=1
beam     num=1 x.origin=0 y.origin=3 angle=270 wavelength=1.550 min.window=-15 max.window=15

#solving

solve  init
outf = sol_hswgpd.str
LOG outf=hs_wg_pd_r.log

solve vgate=-3.0
solve   b1=0.05
solve             b1=0.1
solve   b1=0.15
solve   b1=0.2
solve   b1=0.25
solve   b1=0.3
solve   b1=0.35
solve   b1=0.4
solve   b1=0.45
solve   b1=0.5
solve   b1=0.55
solve   b1=0.6
solve   b1=0.65
solve   b1=0.7
solve   b1=0.75
solve   b1=0.8
solve   b1=0.85
solve   b1=0.9
solve   b1=0.95
solve   b1=1.0
solve   b1=1.05
solve   b1=1.1
solve   b1=1.15
solve   b1=1.2

outf=sol_hswgpd.str master onefile

#
tonyplot hs_wg_pd_r.log

log off

output band.param photogen opt.intens con.band val.band e.mobility h.mobility band.param photogen opt.intens recomb u.srh u.aug u.rad flowlines

save outf=hs_wg_pd.str

tonyplot hs_wg_pd.str

#tonyplot sol_hswgpd.str

quit
```

ATLAS Code – Frequency Response

```
#Michael Benker
#ECE530 Advanced Electronics/Optoelectronics
#UMASSD 5/7/2020
#Final Project: UTC Photodetector

go atlas

mesh auto
x.m l=-75 Spac=3
x.m l=-45 Spac=3
x.m l=-20 Spac=2
x.m l=20 Spac=2
x.m l=45 Spac=3
x.m l=75 Spac =3

# n-contact region to substrate
region bottom  thick = 0.1  material =  InGaAsP NY = 4 x.comp=0.1393  y.comp = 0.3048 donor = 1e19
region bottom  thick = 0.25  material =  InP NY = 4  donor = 1e19
region bottom  thick = 2.0  material =  InP NY = 4

#above n-contact region bottom-up
region top       thick = 0.9  material =  InP   NY = 8 donor = 1e19
region top       thick = 0.1  material =  InP   NY = 8 donor = 1e18
region top       thick = 0.6  material =  InP   NY = 8 donor = 1e16
region top       thick = 0.05  material =  InP   NY = 8 donor = 1e17

#band smooth
region top       thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.1393  y.comp = 0.3048 donor = 1e16
region top       thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.3196 y.comp = 0.6909 donor = 1e16

#absorber
region top   thick = 0.1    mat = InGaAs  NY = 8 x.comp=0.532 donor = 1e16
region top   thick = 0.15   mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 5e17
region top   thick = 0.15   mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 1e18
region top   thick = 0.1    mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 2e18

region top   thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.3196 y.comp = 0.6909 acceptor = 2e18
region top   thick = 0.015  material =  InGaAsP NY = 10 x.comp=0.1393  y.comp = 0.3048 acceptor = 2e18

region top   thick = 0.1  material =  InP   NY = 8 acceptor = 1.5e18
region top   thick = 0.05   mat = InGaAs  NY = 8 x.comp=0.532 acceptor = 2e19

#etch

region  mat = air  x.min=20 x.max = 75 y.max = 0.0 NY = 3
region  mat = air  x.min = -75 x.max = -20 y.max = 0.0 NY = 3

#electrode

electrode name=gate x.min = -20 x.max =20 top
electrode name=np x.min=45 x.max=75 y.max = 0 y.min = 0
electrode name=np x.min=-75 x.max=-45 y.max = 0 y.min = 0

contact name=gate resistance = 0.1

#interface y.min=-1.9 y.max=-1.4 x.min=-1 x.max=1 thermionic=true tunnel=true s.s=true
#Materials
material material=InGaAsP taun0=20.e-9 taup0=33e-9 \
  align=0.4 real.index=3.4 imag.index=0

material material=InGaAs taun0=0.7e-9 taup0=33e-9 \
 real.index=3.43 imag.index=0.2

material  material=InP   taun0=2e-9 taup0=33e-9 \
 align=0.4 real.index=3.17 imag.index=0

#model

mobility material = InP mun=4917.0 mup=150.0 vsatn =  2.6e7 vsatp = 0.66e7 ecritn=11e3 ecritp=4e3 gamman=4 gammap=1
mobility material = InGaAs  mun=11599.0 mup=331.0 vsatn = 2.5e7 vsatp=0.5e7 ecritn=3e3 ecritp=4e3 gamman=4 gammap=1
mobility material = InGaAsP  mun=4600.0 mup=150.0  vsatn = 2.68e7 vsatp=0.6e7 ecritn=6e3 ecritp=4e3 gamman=4 gammap=1

models fldmob srh optr fermidirac conmob print EVSATMOD=1
beam     num=1 x.origin=0 y.origin=5 angle=270 wavelength=1550 min.window=-15 max.window=15

#waveform beam=1 amplitude=1e3  frequency=5e9 number=1 periods=1000 sinusoid
#solving
METHOD HALFIMPL

solve  init
outf = sol_hswgpd.str
LOG outf=hs_wg_pd_r.log

solve vgate=-3.0

LOG off

LOG outf=transient_mb.log
SOLVE B1=1.0 RAMPTIME=1E-9 TSTOP=1E-9 TSTEP=1E-12
SOLVE B1=0.0 RAMPTIME=1E-9 TSTOP=20E-9 TSTEP=1E-12

tonyplot transient_mb.log
#solve            b1=.001 ss.phot ss.light=0.001 beam=1 freq=1e5
#solve            b1=.001 ss.phot ss.light=0.001 beam=1 freq=1e6
outf=sol_hswgpd.str master onefile
log off

log outf=mbutcpd_fdom2.log
FOURIER INFILE=transient_mb.log OUTFILE=mbutcpd_fdom2.log T.START=0  T.STOP=20E-9 INTERPOLATE
tonyplot mbutcpd_fdom2.log

LOG off

output band.param ramptime TRANS.ANALY  photogen opt.intens con.band val.band e.mobility h.mobility band.param photogen opt.intens recomb u.srh u.aug u.rad flowlines

save outf=hs_wg_pd.str

#LOG outf=mbutcpd_fdom.log

tonyplot hs_wg_pd.str

quit
```

References

- ATLAS TCAD Manual
- Swiss Federal Institute of Technology Zurich – Prof. Jaeckel- http://people.ee.ethz.ch/~fyuriy/oe/
- SMU Photonic Study Group 2003 https://s2.smu.edu/ee/smuphotonics/GainManual/HTM_GainManual/book.htm#_Toc58312414
- https://www.silvaco.com