

7. Appendix B - Device Files

7.1 Listing 1 - Multi-Quantum Well Solar Cell

```
grid length=0.15 points=50
grid length=0.10 points=300
grid length=0.35 points=50
grid length=0.18 points=100
grid length=0.49 points=400
grid length=0.43 points=50
grid length=0.20 points=50

structure material=gaas alloy=al length=0.50 conc=.4
structure material=gaas alloy=al length=0.30 conc=.4
electron_energy_lifetime length=0.2 value=1e-16
electron_energy_lifetime length=0.6 value=1e-12

region bulk length=0.8

repeat start

structure material=gaas alloy=al length=0.01 conc=0.0
electron_energy_lifetime length=0.01 value=1e-9
structure material=gaas alloy=al length=0.01 conc=.4
electron_energy_lifetime length=0.01 value=1e-12
region qw length=0.01
region bulk length=0.01

repeat=15

structure material=gaas alloy=al length=0.30 conc=.4
structure material=gaas alloy=al length=0.50 conc=.4
electron_energy_lifetime length=0.6 value=1e-12
electron_energy_lifetime length=0.2 value=1e-16
region bulk length=0.8

doping length=0.5 Na=5e17
doping length=0.9
doping length=0.5 Nd=5e17
```

7.2 Listing 2 - Standard Delta Doped VCSEL

```
radius=3.5

ELECTRON_MOBILITY Segments=2 length=6.4512
Start_x=0.0 end_x=0.45 Value=((8000-22000*x+10000*x^2)*(300/C)^2.3)/
(1+5.51e-17*(N+A))^0.233
Start_x=0.45 end_x=1.0 Value=((-255+1160*x-720*x^2)*(300/C)^2.3)/
(1+5.51e-17*(N+A))^0.233

HOLE_MOBILITY length=6.4512 value=((370-970*x+740*x^2)*(300/C)^2.7)/
```

$$(1+3.17e-17*(N+A))^{.266}$$

cavity surface area=38.484 length=1.707264

mirror metal position=0 ref=0.9975

mirror metal position=6.4512 ref=0.999

#####

Top DBR

structure material=gaas alloy=al length=.0044 conc=0.00

grid length=.0034 points=5

grid length=.0030 points=10

structure material=gaas alloy=al length=.0515 conc=0.16

grid length=.0445 points=10

structure material=gaas alloy=al length=.0099 conc=0.58

grid length=.0199 points=20

structure material=gaas alloy=al length=.0604 conc=1.00

grid length=.0504 points=10

doping length=0.1262 Na=2e19 Na_deg=4 Na_level=0.026

region length=0.1262 bulk

REFRACTIVE_INDEX length=0.1262 model=oscillator_refractive_index

repeat start

structure material=gaas alloy=al length=.0099 conc=0.58

grid length=0.0199 points=20

structure material=gaas alloy=al length=.0515 conc=0.16

grid length=0.0415 points=10

structure material=gaas alloy=al length=.0099 conc=0.58

grid length=0.0199 points=20

structure material=gaas alloy=al length=.0604 conc=1.00

grid length=0.0504 points=10

doping length=.1317 Na=2e19 Na_deg=4 Na_level=0.026

region length=.1317 bulk

REFRACTIVE_INDEX length=0.1317 model=oscillator_refractive_index

repeat=3

repeat start

structure material=gaas alloy=al length=.0099 conc=0.58

grid length=0.0199 points=20

doping length=.0015 Na=1.466e19-(9.66e18/.0015)*d Na_deg=4 Na_level=0.026

doping length=.0069 Na=5e18 Na_deg=4 Na_level=0.026

doping length=.0015 Na=5e18+(9.66e18/.0015)*d Na_deg=4 Na_level=0.026

structure material=gaas alloy=al length=.0515 conc=0.16

grid length=0.0415 points=10

doping length=.0015 Na=1.466e19-(9.66e18/.0015)*d Na_deg=4 Na_level=0.026

doping length=.0485 Na=5e18 Na_deg=4 Na_level=0.026

doping length=.0015 Na=5e18+(2.5e19/.0015)*d Na_deg=4 Na_level=0.026

structure material=gaas alloy=al length=.0099 conc=0.58

```

grid length=0.0199 points=20
doping length=.0015 Na=3e19-(2.5e19/.0015)*d Na_deg=4 Na_level=0.026
doping length=.0069 Na=5e18 Na_deg=4 Na_level=0.026
doping length=.0015 Na=5e18+(2.5e19/.0015)*d Na_deg=4 Na_level=0.026

structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0504 points=10
doping length=.0015 Na=3e19-(2.5e19/.0015)*d Na_deg=4 Na_level=0.026
doping length=.0574 Na=5e18 Na_deg=4 Na_level=0.026
doping length=.0015 Na=5e18+(9.66e18/.0015)*d Na_deg=4 Na_level=0.026

region length=.1317 bulk
REFRACTIVE_INDEX length=0.1317 model=oscillator_refractive_index

repeat=14

doping length=.0015 Na=1.466e19-(9.66e18/.0015)*d Na_deg=4 Na_level=0.026

#####
# Active Region

grid length=0.005 points=20
grid length=0.0841 points=200
grid length=0.0600 points=600
grid length=0.0841 points=200
grid length=0.005 points=20

structure material=gaas alloy=al length=.0050 conc=0.58
structure material=gaas alloy=al length=.0891 conc=0.16
doping length=.0035 Na=3e18 Na_deg=4 Na_level=0.026
doping length=.0891 Na=1e17 Na_deg=4 Na_level=0.026
region length=.0941 bulk
REFRACTIVE_INDEX length=0.0941 model=oscillator_refractive_index

structure material=gaas alloy=al length=.0080 conc=0.00
structure material=gaas alloy=al length=.0080 conc=0.16
structure material=gaas alloy=al length=.0080 conc=0.00
structure material=gaas alloy=al length=.0080 conc=0.16
structure material=gaas alloy=al length=.0080 conc=0.00
doping length=.04
region length=.0080 qw
REFRACTIVE_INDEX length=0.0080 value=5
region length=.0080 bulk
REFRACTIVE_INDEX length=0.0080 model=oscillator_refractive_index
region length=.0080 qw
REFRACTIVE_INDEX length=0.0080 value=5
region length=.0080 bulk
REFRACTIVE_INDEX length=0.0080 model=oscillator_refractive_index
region length=.0080 qw
REFRACTIVE_INDEX length=0.0080 value=5

structure material=gaas alloy=al length=.0891 conc=0.16
structure material=gaas alloy=al length=.0050 conc=0.58
doping length=.0891

```

```

doping length=.0050
region length=.0941 bulk
REFRACTIVE_INDEX length=0.0941 model=oscillator_refractive_index

#####
# Bottom DBR

repeat start

structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0504 points=10
structure material=gaas alloy=al length=.0099 conc=0.58
grid length=0.0199 points=20
structure material=gaas alloy=al length=.0515 conc=0.16
grid length=0.0415 points=10
structure material=gaas alloy=al length=.0099 conc=0.58
grid length=0.0199 points=20
doping length=.1317 Nd=3e18 Nd_deg=2 Nd_level=0.005
region length=.1317 bulk
REFRACTIVE_INDEX length=0.1317 model=oscillator_refractive_index

repeat=28

structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0504 points=10
structure material=gaas alloy=al length=.0099 conc=0.58
grid length=0.0199 points=20
structure material=gaas alloy=al length=.1000 conc=0.00
grid length=0.0950 points=40
doping length=.1703 Nd=3e18 Nd_deg=2 Nd_level=0.005
region length=.1703 bulk
REFRACTIVE_INDEX length=0.1703 model=oscillator_refractive_index

```

7.3 Listing 3 - 1.5 Periods of an n-type DBR

```

ELECTRON_MOBILITY Segments=2 length=0.1921
Start_x=0.0 end_x=0.45 Value=((8000-22000*x+10000*x^2)*(300/C)^2.3)/
(1+5.51e-17*(N+A))^0.233
Start_x=0.45 end_x=1.0 Value=((-255+1160*x-720*x^2)*(300/C)^2.3)/
(1+5.51e-17*(N+A))^0.233

HOLE_MOBILITY length=0.1921 value=((370-970*x+740*x^2)*(300/C)^2.7)/
(1+3.17e-17*(N+A))^0.266

structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0554 points=30

#standard structure
#structure material=gaas alloy=al length=.0099 conc=.58
#improved structure
structure material=gaas alloy=al length=.0099 conc=.3
grid length=0.0199 points=80

```

```

structure material=gaas alloy=al length=.0515 conc=0.16
grid length=0.0415 points=30

#standard structure
#structure material=gaas alloy=al length=.0099 conc=.58
#improved structure
structure material=gaas alloy=al length=.0099 conc=.3
grid length=0.0199 points=80

structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0554 points=30

doping length=.1921 Nd=3e18 Nd_deg=2 Nd_level=0.005
region length=.1921 bulk
REFRACTIVE_INDEX length=0.1921 model=oscillator_refractive_index

```

7.4 Listing 4 - 1.5 Periods of a p-type DBR

```

ELECTRON_MOBILITY Segments=2 length=0.1921
Start_x=0.0 end_x=0.45 Value=((8000-22000*x+10000*x^2)*(300/C)^2.3)/
(1+5.51e-17*(N+A))^0.233
Start_x=0.45 end_x=1.0 Value=(((-255+1160*x-720*x^2)*(300/C)^2.3)/
(1+5.51e-17*(N+A))^0.233

HOLE_MOBILITY length=0.1921 value=((370-970*x+740*x^2)*(300/C)^2.7)/
(1+3.17e-17*(N+A))^0.266

structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0554 points=30

#standard structure
#structure material=gaas alloy=al length=.0099 conc=0.58
#improved structure
structure material=gaas alloy=al length=.0099 conc=1-(0.84/0.0099)*d
grid length=0.0199 points=80

structure material=gaas alloy=al length=.0515 conc=0.16
grid length=0.0415 points=30

#standard structure
#structure material=gaas alloy=al length=.0099 conc=0.58
#improved structure
structure material=gaas alloy=al length=.0099 conc=0.16+(0.84/0.0099)*d
grid length=0.0199 points=80

structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0554 points=30

doping length=.1921 Na=5e18 Na_deg=4 Na_level=0.026
region length=.1921 bulk
REFRACTIVE_INDEX length=0.1921 model=oscillator_refractive_index

```

7.5 Listing 5 - Improved n-type DBR

```

ELECTRON_MOBILITY Segments=2 length=3.748
Start_x=0.0 end_x=0.45 Value=((8000-22000*x+10000*x^2)*(300/C)^2.3)/
(1+5.51e-17*(N+A))^0.233
Start_x=0.45 end_x=1.0 Value=(((-255+1160*x-720*x^2)*(300/C)^2.3)/
(1+5.51e-17*(N+A))^0.233

HOLE_MOBILITY length=3.748 value=((370-970*x+740*x^2)*(300/C)^2.7)/
(1+3.17e-17*(N+A))^0.266

structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0554 points=30
grid length=0.0050 points=10

repeat start

#standard structure
#structure material=gaas alloy=al length=.0099 conc=.58
#improved structure
structure material=gaas alloy=al length=.0099 conc=.30
grid length=0.0149 points=30

structure material=gaas alloy=al length=.0515 conc=0.16
grid length=0.0415 points=15

#standard structure
#structure material=gaas alloy=al length=.0099 conc=.58
#improved structure
structure material=gaas alloy=al length=.0099 conc=.30
grid length=0.0199 points=40

structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0504 points=15
grid length=0.0050 points=10

repeat=28

doping length=3.748 Nd=3e18 Nd_deg=2 Nd_level=0.005
region length=3.748 bulk
REFRACTIVE_INDEX length=3.748 model=oscillator_refractive_index

```

7.6 Listing 6 - Improved p-type DBR

```

ELECTRON_MOBILITY Segments=2 length=1.9042
Start_x=0.0 end_x=0.45 Value=((8000-22000*x+10000*x^2)*(300/C)^2.3)/
(1+5.51e-17*(N+A))^0.233
Start_x=0.45 end_x=1.0 Value=(((-255+1160*x-720*x^2)*(300/C)^2.3)/
(1+5.51e-17*(N+A))^0.233

HOLE_MOBILITY length=1.9042 value=((370-970*x+740*x^2)*(300/C)^2.7)/
(1+3.17e-17*(N+A))^0.266

```

```

structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0554 points=30
grid length=0.0050 points=10

repeat start

#standard structure
#structure material=gaas alloy=al length=.0099 conc=.58
#improved structure
structure material=gaas alloy=al length=.0099 conc=1-(0.84/0.0099)*d
grid length=0.0149 points=30

structure material=gaas alloy=al length=.0515 conc=0.16
grid length=0.0415 points=15

#standard structure
#structure material=gaas alloy=al length=.0099 conc=.58
#improved structure
structure material=gaas alloy=al length=.0099 conc=0.16+(0.84/0.0099)*d
grid length=0.0199 points=40

structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0504 points=15
grid length=0.0050 points=10

repeat=14

doping length=1.9042 Na=5e18 Na_deg=4 Na_level=0.026
region length=1.9042 bulk
REFRACTIVE_INDEX length=1.9042 model=oscillator_refractive_index

```

7.7 Listing 7 - Improved VCSEL

```

radius=3.5

ELECTRON_MOBILITY Segments=2 length=6.4243451
Start_x=0.0 end_x=0.45 Value=((8000-22000*x+10000*x^2)*(300/C)^2.3)/
(1+5.51e-17*(N+A))^0.233
Start_x=0.45 end_x=1.0 Value=(((-255+1160*x-720*x^2)*(300/C)^2.3)/
(1+5.51e-17*(N+A))^0.233

HOLE_MOBILITY length=6.4243451 value=((370-970*x+740*x^2)*(300/C)^2.7)/
(1+3.17e-17*(N+A))^0.266

cavity surface area=38.484 length=1.707264

mirror metal position=0 ref=0.9975
mirror metal position=6.4243451 ref=0.999

#####
# Top DBR

structure material=gaas alloy=al length=.0044 conc=0.00

```

```

grid length=.0034 points=5
grid length=.0030 points=10
structure material=gaas alloy=al length=.0515 conc=0.16
grid length=.0445 points=10
structure material=gaas alloy=al length=.0099 conc=0.16+(0.84/.0099)*d
grid length=.0199 points=20
structure material=gaas alloy=al length=.0604 conc=1.00
grid length=.0504 points=10
doping length=0.1262 Na=2e19 Na_deg=4 Na_level=0.026
region length=0.1262 bulk
REFRACTIVE_INDEX length=0.1262 model=oscillator_refractive_index

```

```
repeat start
```

```

structure material=gaas alloy=al length=.0099 conc=1.00-(0.84/.0099)*d
grid length=0.0199 points=20
structure material=gaas alloy=al length=.0515 conc=0.16
grid length=0.0415 points=10
structure material=gaas alloy=al length=.0099 conc=0.16+(0.84/.0099)*d
grid length=0.0199 points=20
structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0504 points=10
doping length=.1317 Na=2e19 Na_deg=4 Na_level=0.026
region length=.1317 bulk
REFRACTIVE_INDEX length=0.1317 model=oscillator_refractive_index

```

```
repeat=3
```

```
repeat start
```

```

structure material=gaas alloy=al length=.0099 conc=1.00-(0.84/.0099)*d
grid length=0.0199 points=20
doping length=.0099 Na=5e18 Na_deg=4 Na_level=0.026
structure material=gaas alloy=al length=.0515 conc=0.16
grid length=0.0415 points=10
doping length=.0515 Na=5e18 Na_deg=4 Na_level=0.026
structure material=gaas alloy=al length=.0099 conc=0.16+(0.84/.0099)*d
grid length=0.0199 points=20
doping length=.0099 Na=5e18 Na_deg=4 Na_level=0.026
structure material=gaas alloy=al length=.0604 conc=1.00
grid length=0.0504 points=10
doping length=.0604 Na=5e18 Na_deg=4 Na_level=0.026

```

```

region length=.1317 bulk
REFRACTIVE_INDEX length=0.1317 model=oscillator_refractive_index

```

```
repeat=14
```

```

#####
# Active Region

```

```

grid length=0.005 points=20
grid length=0.0841 points=200
grid length=0.0600 points=600

```


grid length=0.0841 points=200
 grid length=.0047641 points=20

structure material=gaas alloy=al length=.0050 conc=1.00-(0.84/.0050)*d
 structure material=gaas alloy=al length=.0891 conc=0.16
 doping length=.0050 Na=3e18 Na_deg=4 Na_level=0.026
 doping length=.0891 Na=1e17 Na_deg=4 Na_level=0.026
 region length=.0941 bulk
 REFRACTIVE_INDEX length=0.0941 model=oscillator_refractive_index

structure material=gaas alloy=al length=.0080 conc=0.00
 structure material=gaas alloy=al length=.0080 conc=0.16
 structure material=gaas alloy=al length=.0080 conc=0.00
 structure material=gaas alloy=al length=.0080 conc=0.16
 structure material=gaas alloy=al length=.0080 conc=0.00
 doping length=.04
 region length=.0080 qw
 REFRACTIVE_INDEX length=0.0080 value=5
 region length=.0080 bulk
 REFRACTIVE_INDEX length=0.0080 model=oscillator_refractive_index
 region length=.0080 qw
 REFRACTIVE_INDEX length=0.0080 value=5
 region length=.0080 bulk
 REFRACTIVE_INDEX length=0.0080 model=oscillator_refractive_index
 region length=.0080 qw
 REFRACTIVE_INDEX length=0.0080 value=5

structure material=gaas alloy=al length=.0891 conc=0.16
 structure material=gaas alloy=al length=.0047641 conc=0.30
 doping length=.0891
 doping length=.0047641
 region length=.0938641 bulk
 REFRACTIVE_INDEX length=.0938641 model=oscillator_refractive_index

 # Bottom DBR

repeat start

structure material=gaas alloy=al length=.0604 conc=1.00
 grid length=0.0504 points=10
 structure material=gaas alloy=al length=.009433 conc=0.30
 grid length=0.019433 points=20
 structure material=gaas alloy=al length=.0515 conc=0.16
 grid length=0.0415 points=10
 structure material=gaas alloy=al length=.009433 conc=0.30
 grid length=0.019433 points=20
 doping length=.130766 Nd=3e18 Nd_deg=2 Nd_level=0.005
 region length=.130766 bulk
 REFRACTIVE_INDEX length=0.130766 model=oscillator_refractive_index

repeat=28

structure material=gaas alloy=al length=.0604 conc=1.00

```

grid length=0.0504 points=10
structure material=gaas alloy=al length=.009433 conc=0.30
grid length=0.019433 points=20
structure material=gaas alloy=al length=.1000 conc=0.00
grid length=0.0950 points=40
doping length=.169833 Nd=3e18 Nd_deg=2 Nd_level=0.005
region length=.169833 bulk
REFRACTIVE_INDEX length=.169833 model=oscillator_refractive_index

```

7.8 Listing 8 - Test pn Diode

```

grid length=.45 points=100
grid length=.1 points=200
grid length=.45 points=100

structure length=1.00 material=si

doping length=.5 Na=1e17
doping length=.5 Nd=3e17

```

7.9 Listing 9 - Test pn Photodetector

```

grid length=.45 points=100
grid length=.1 points=200
grid length=.45 points=100

structure length=1.00 material=gaas

doping length=.5 Na=1e17
doping length=.5 Nd=3e17

```

7.10 Listing 10 - Test Resistor

```

grid length=1.0 points=200

structure material=gaas length=1.0

doping length=1.0 Nd=1e17

```