Scilab Textbook Companion for Optoelectronics And Fiber Optics Communication by C. K. Sarkar and D. C. Sarkar [1]

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Book Description

Title: Optoelectronics And Fiber Optics Communication

Author: C. K. Sarkar and D. C. Sarkar

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

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Chapter 1

Introduction to Fiber Communications

Scilab code Exa 1.1 Critical angle acceptance angle numerical aperture light coupl

```

//Optoelectronics and Fiber Optics Communication by C.R. Sarkar and D.C. Sarkar
//Example 1.1
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
n1=1.500;//refractive index of core
n2=1.450;//refractive index of cladding
thetac=asind(n2/n1);//critical angle for core-cladding(in degrees)
phim=90-thetac;//corresponding angle of obliqueness(in degrees)
```

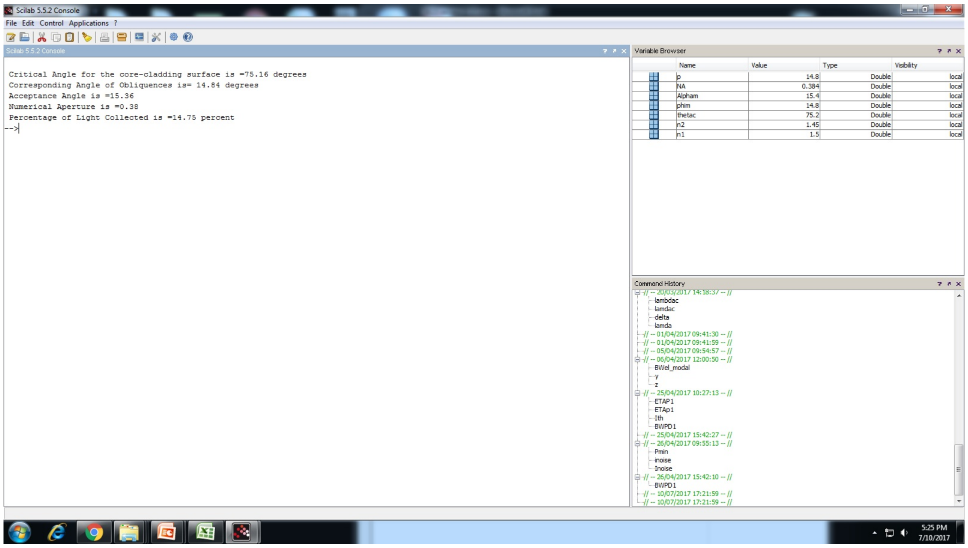

Figure 1.1: Critical angle acceptance angle numerical aperture light coupled

```
mprintf("\n Critical Angle for the core−cladding surface is =%.2f degrees ",thetac);
mprintf("\n Corresponding Angle of Obliquences is= %.2f degrees",phim);
Alpham=asind((n1/n2)* sind(phim));//acceptance angle
mprintf("\n Acceptance Angle is =%.2f ",Alpham);
NA=(((n1+n2)*(n1-n2))^0.5);//numerical aperture of the fiber
mprintf("\n Numerical Aperture is =%.2f ",NA);
p=((NA)^2 )*100;//percentage of light collected
mprintf("\n Percentage of Light Collected is =%.2f percent",p);
//the answers vary due to rounding
```

Scilab code Exa 1.2 `Acceptance angle`

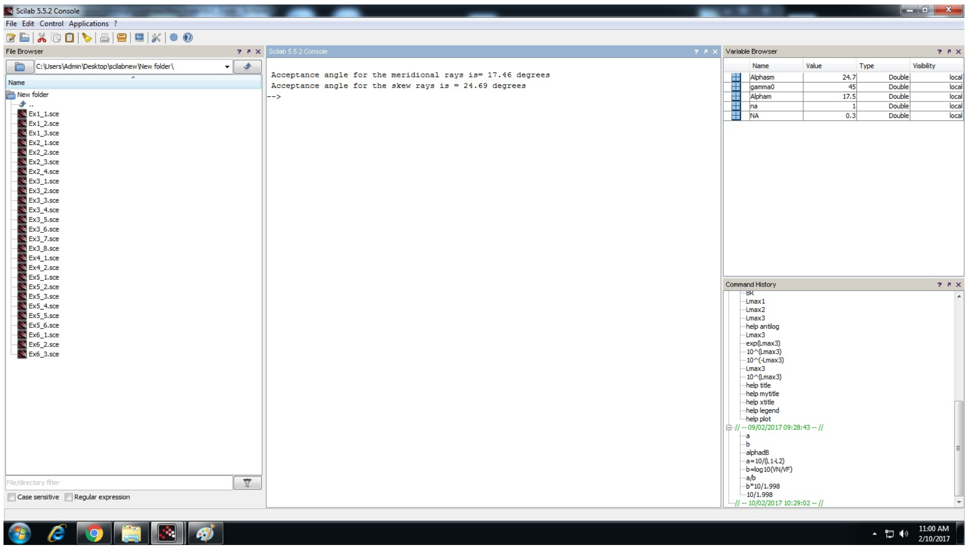

Figure 1.2: Acceptance angle

```

//Optoelectronics and Fiber Optics Communication by C.R. Sarkar and D.C. Sarkar
//Example 1.2
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
NA=0.3;//numerical aperture of the optical fiber
na=1;//refractive index of air
Alpham=(asind(NA));//acceptance angle for the meridional rays
gamma0=45;//in degrees
Alphasm=(asind(NA)/cosd(gamma0));//acceptance angle for skew rays
mprintf("\n Acceptance angle for the meridional rays is= %.2f degrees",Alpham);
```

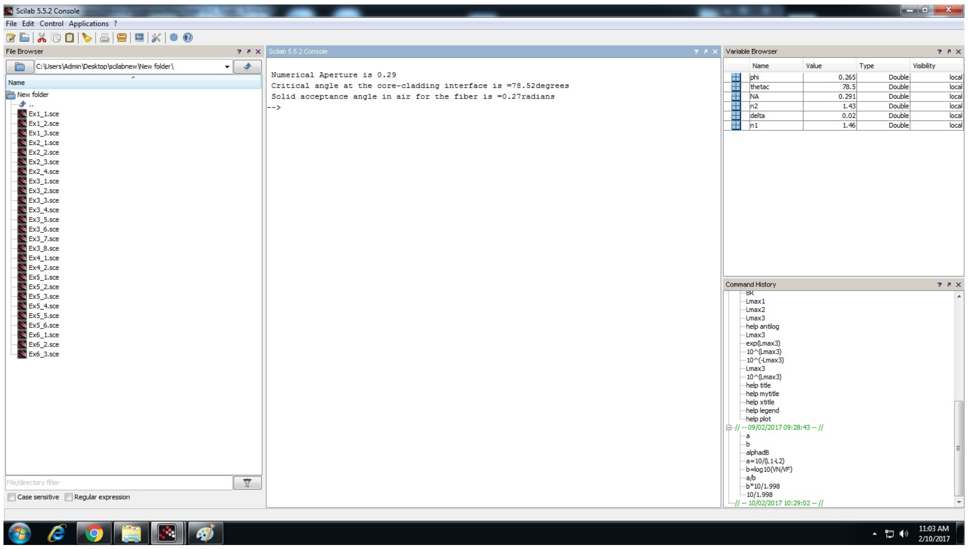

Figure 1.3: numerical aperture solid acceptance angle critical angle

```
mprintf("\n Acceptance angle for the skew rays is =
    %.2f degrees",Alphasm);
//The answer vary due to rounding
```

Scilab code Exa 1.3 numerical aperture solid acceptance angle critical angle

```

//Optoelectronics and Fiber Optics Communication by
    C.R. Sarkar and D.C. Sarkar
//Example 1.3
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

```

```
//given
n1=1.46;//refractive index of the core of W-step
    index fiber
delta=0.02;//relative refractive index between the
    core and the cladding
n2=n1-(delta*n1);//refractive index of the cladding
NA=(((n1+n2)*(n1-n2))^0.5);//numerical aperture of
    the fiber
thetac=asind(n2/n1);//critical angle at the core
    cladding interface
phi=%pi*(NA^2);//solid acceptance angle in air for
    the fiber
mprintf("\n Numerical Aperture is %.2f",NA);
mprintf("\n Critical angle at the core-cladding
    interface is =%.2fdegrees",thetac);
mprintf("\n Solid acceptance angle in air for the
    fiber is =%.2fradians",phi);
//the answer vary due to rounding
```

Chapter 2

Electromagnetic Wave Propagation Through Optical Fiber

Scilab code Exa 2.1 Refractive Index normalized frequency guided modes

```
//Optoelectronics and Fiber Optics Communication by
   C.R. Sarkar and D.C. Sarkar
//Example 2.1
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
lamda=85*10^-8;//wavelength of multimode fiber m
d=70e-6;//core diameter of the multimode fiber in m
n1=1.46;//refractive index of the fiber
delta=0.015;//relative refractive index difference
```

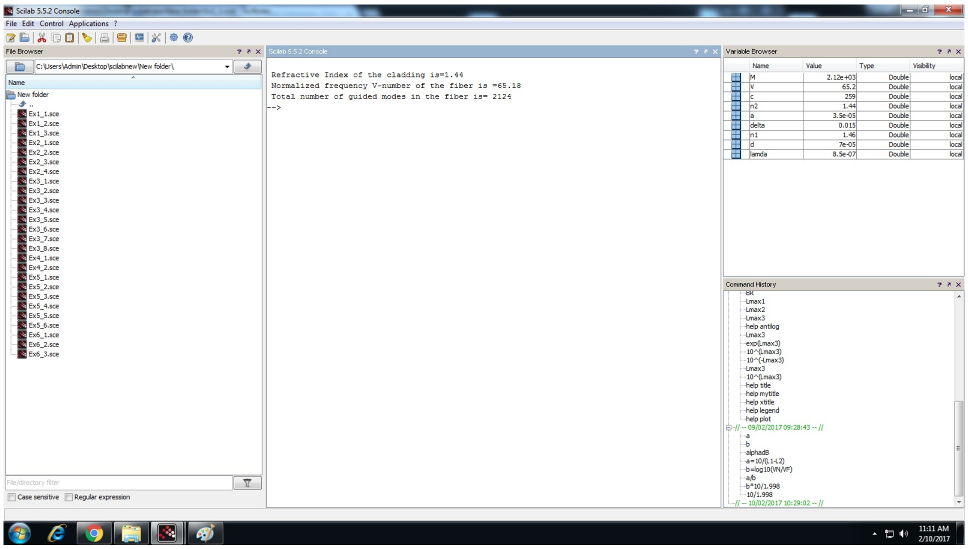

Figure 2.1: Refractive Index normalized frequency guided modes

```
a=d/2;//radius=d/2 of core in m
n2=n1-(delta*n1);//refractive index of cladding
c=2*%pi*a/lamda;//constant part of the V-Number formula
V=c*((n1^2-n2^2))^0.5;// V-number
M=V^2/2;//total number of guided modes in the stepindex fiber
mprintf("\n Refractive Index of the cladding is=%.2f ",n2);
mprintf("\n Normalized frequency V-number of the fiber is =%.2f ",V);
mprintf("\n Total number of guided modes in the fiber is= %.0f ",M);
//The answers vary due to rounding
```

Scilab code Exa 2.2 `core diameter`

```
//Optoelectronics and Fiber Optics Communication by C.R. Sarkar and D.C. Sarkar
//Example 2.2
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
n1=1.48;//core refractive index of a step-index fiber
delta=0.015;//relative index difference between the core and cladding
lamda=85*10^-8;//wavelength of the fiber in m
V=2.405;//value of V-number for single mode
c=(2*delta)^0.5;//constant value
a=(V*lamda)/(2*%pi*n1*c);//value of radius of core diameter in m
d=2*a;//diameter of core diameter in m
mprintf("\n Core diameter of the step index fiber is =%.2f um ",d*1e6);
delta1=0.0015;//relative index difference between the core and the cladding
c1=(2*delta1)^0.5;//constant value
a1=(V*lamda)/(2*%pi*n1*c1);//value of radius of core diameter in m
d1=2*a1;//diameter of core diameter in m
mprintf("\n Core diameter of the step index fiber is = %.2f um ",d1*1e6);//multiplication by 1e6 to convert the unit from m to um
//the answer vary due to rounding
```

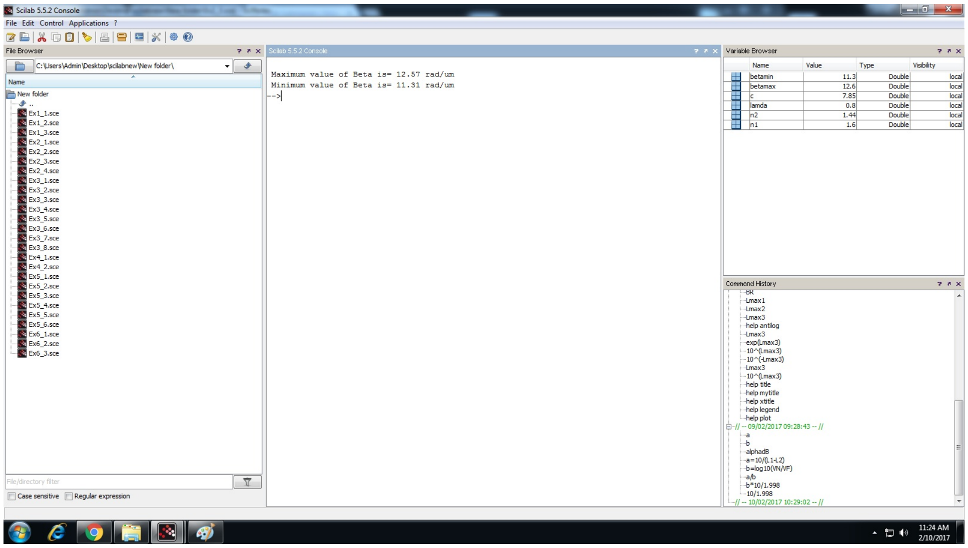

Figure 2.2: phase constant

Scilab code Exa 2.3 `phase constant`

```

//Optoelectronics and Fiber Optics Communication by
    C.R. Sarkar and D.C. Sarkar
//Example 2.3
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
n1=1.6;//core and cladding refractive index of first
    fiber
n2=1.44;//core and cladding refractive index of
    second fiber
lamda=0.8;//wavelength of the electromagnetic wave
    in um
c=(2*%pi)/lamda;//constant value propagation
```

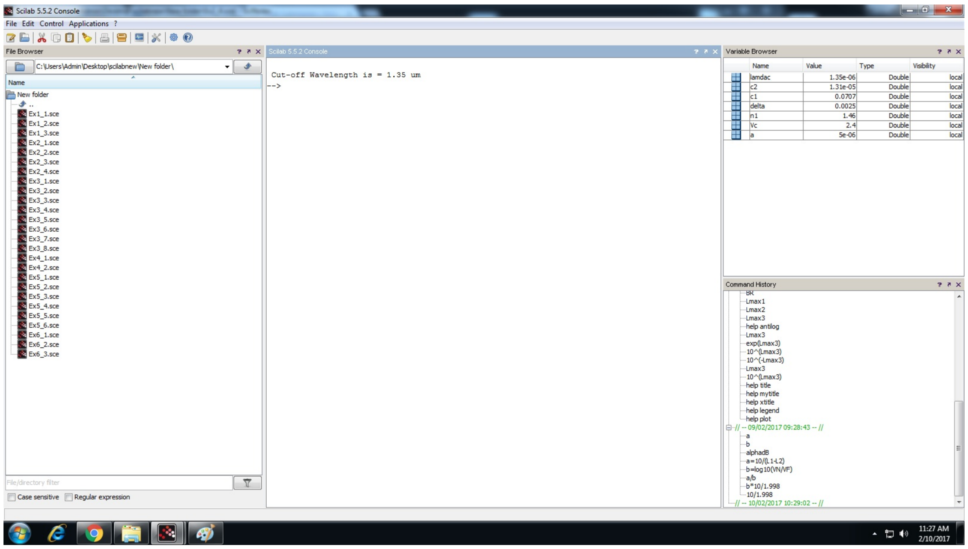

Figure 2.3: cutoff wavelength

```
    constant
betamax=c*n1;//maximum value of maximum value of
    beta
betamin=c*n2;//minimum value of minimum value of
    beta
mprintf("\n Maximum value of Beta is= %.2f rad/um ",
    betamax);
mprintf("\n Minimum value of Beta is= %.2f rad/um",
    betamin);
//The answer vary due to rounding
```

Scilab code Exa 2.4 `cutoff wavelength`

```

//Optoelectronics and Fiber Optics Communication by
    C.R. Sarkar and D.C. Sarkar
```

```
//Example 2.4
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
a=5*10^-6;//radius in m
Vc=2.405;//cut off value of V-parameter for single mode
n1=1.46;//refractive index of the core
delta=0.0025;//refractive index difference between the core and cladding
c1=(2*delta)^0.5;//constant value
c2=(2*%pi*a)/Vc;//constant value
lamdac=c2*n1*c1;//cut off wavelength in m
mprintf("\n Cut-off Wavelength is = %.2f um ",lamdac*1e6);//multiplication by 1e6 to convert the unit from m to um
//The answer vary due to rounding
```

Scilab code Exa 2.5 number of guided mode and power flow in core cladding

```

//Optoelectronics and Fiber Optics Communication by C.R. Sarkar and D.C. Sarkar
//Example 2.5
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;
```

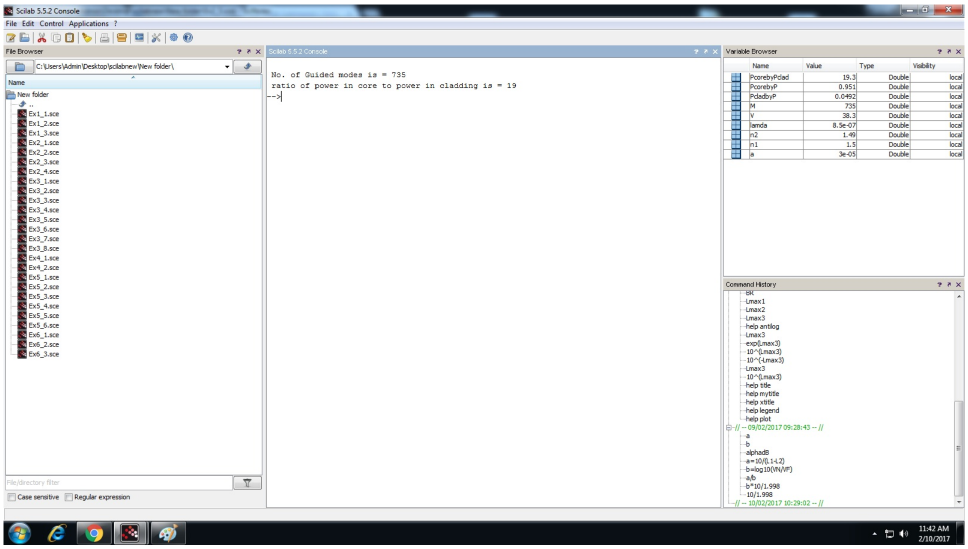

Figure 2.4: number of guided mode and power flow in core cladding

```

//given
a=30*10^-6;//radius in m
n1=1.50;//refractive index of the core
n2=1.49;//refractive index of the cladding
lamda=0.85e-6//operating wavelength in m
V=((2*%pi*a/lamda))*sqrt(n1^2-n2^2)//V number
M=(1/2)*V^2//no. of guided modes in fiber
mprintf("\n No. of Guided modes is = %.0f ",M);
PcladbyP=(4/3)*M^-0.5//power in cladding to total
    power
PcorebyP=1-PcladbyP//power in core to total power
PcorebyPclad=PcorebyP/PcladbyP//power in core to
    power in cladding
mprintf("\n ratio of power in core to power in
    cladding is = %.0f ",PcorebyPclad);
//The answer vary due to rounding
```

Chapter 3

Losses and Dispersions in Optical Fiber

Scilab code Exa 3.1 `Signal attenuation calculation`

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 3.1
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
Pin=100;//average optical power in microwatts
Pout=2.5;//average output power in microwatts
L=10;//length of fiber in Km
L1=11//Length of fiber in Km
Ls=0.8//attenuation per splice in dB
ns=3//no of splices
u=1/L;
```

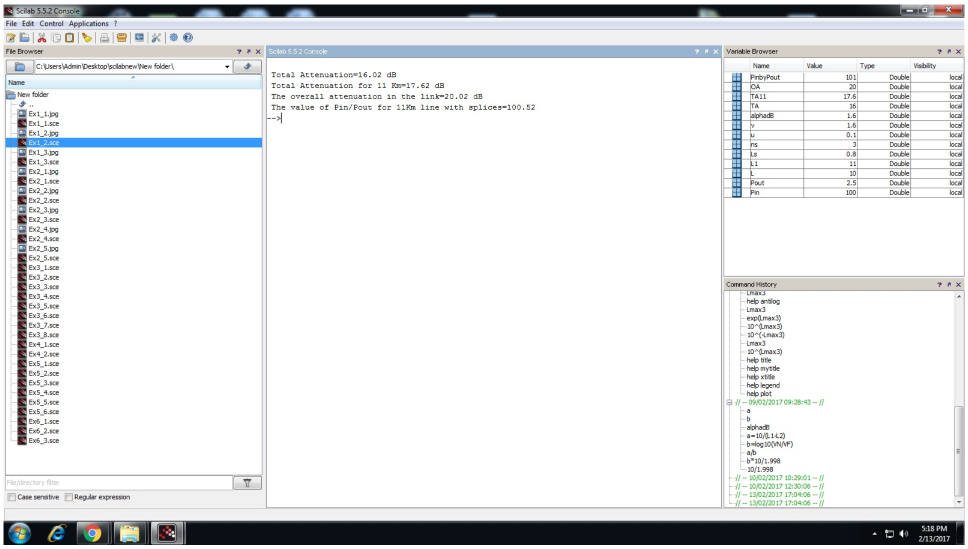

Figure 3.1: Signal attenuation calculation

```
v=log10(Pin/Pout);
alphadB=u*10*v;//total attenuation per Km
TA=alphadB*L;
mprintf("\n Total Attenuation=%.2f dB",TA);
TA11=alphadB*L1;//total attenuation for 11 Km
mprintf("\n Total Attenuation for 11 Km=%.2f dB",
    TA11);
OA=TA11+ns*Ls;//overall attenuation in the link
mprintf("\n The overall attenuation in the link=%.2f
    dB",OA);
PinbyPout=10^(OA/10);//the value of Pin/Pout for 11
    Km line with splices
mprintf("\n The value of Pin/Pout for 11Km line with
    splices=%.2f",PinbyPout);
//the answer vary due to rounding
```

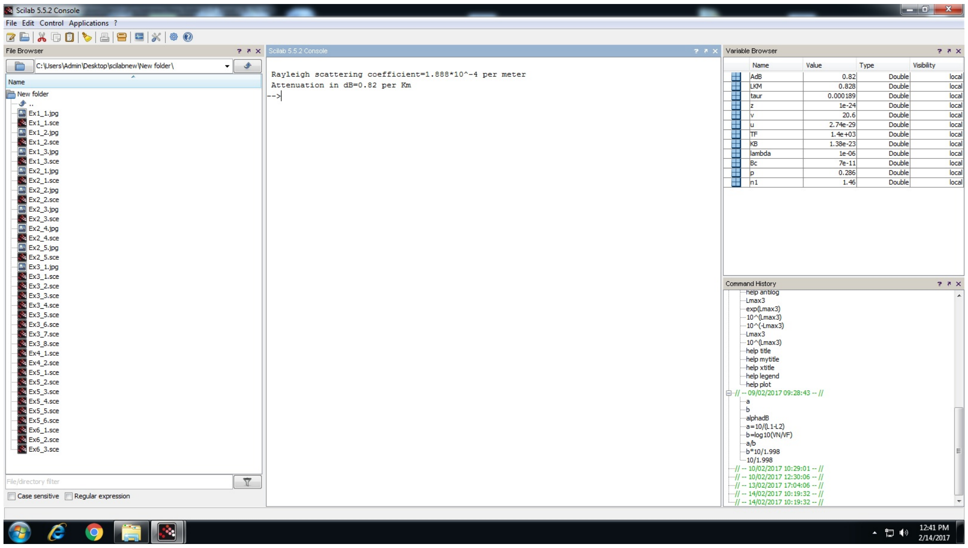

Figure 3.2: Attenuation

Scilab code Exa 3.2 `Attenuation`

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 3.2
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
n1=1.46;//refractive inde for the silica
p=0.286;//photo elastic coefficient for the silica
Bc=7e-11;//isothermal compressibility in m^2/N
lambda=1e-6;//wavelength in meters
KB=1.38e-23;//Boltzman constant in J/K
TF=1400//fictive temperature in K
u=8*(%pi^3)*KB*Bc*TF*p^2;// partial product
v=(n1)^8;//partial product
```

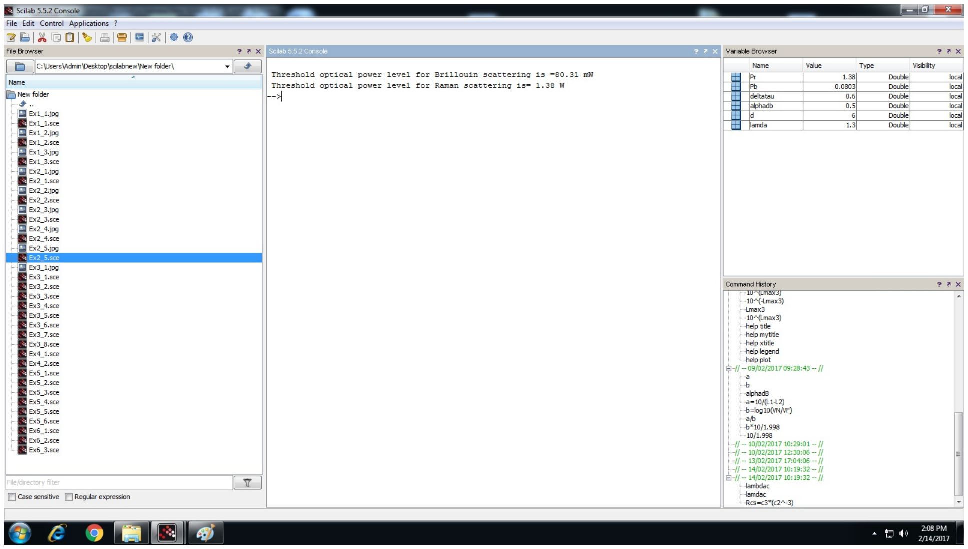

Figure 3.3: Threshold optical power for SBS and SRS

```
z=(lambda)^4;//partial product
taur=[(u*v)/(z*3)];//Rayleigh scattering coefficient
    in per Km
mprintf("\n Rayleigh scattering coefficient=%.3f
    *10^-4 per meter",taur*10^4);//multiplication by
    1e4 to convert the unit to !0^-4 per Km
LKM=exp(-taur*1e3);//transmission loss factor of
    fiber per m
AdB=10*log10(1/LKM);//Attenuation in dB
mprintf("\n Attenuation in dB=%.2fdB per Km",AdB);
//the answer vary due to rounding
```

Scilab code Exa 3.3 `Threshold optical power for SBS and SRS`

```
//Optoelectronics and Fiber Optics Communication by
    C.R. Sarkar and D.C. Sarkar
//Example 3.3
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given

lamda=1.3;//wavelength in mm
d=6;//diameter of the fiber in um
alphadb=0.5//attenuation in dB
deltatau=0.6;//laser source bandwidth in GHz
Pb=(4.4*10^-3)*(d*d)*(lamda*lamda)*(alphadb)*(
    deltatau);//threshold optical power level for
    Brillouin scattering in watts
Pr=(5.9*10^-2)*(d*d)*(lamda)*(alphadb);//threshold
    optical power level for Raman Scattering in watts
mprintf("\n Threshold optical power level for
    Brillouin scattering is =%.2f mW",Pb*1e3);//
    multiplication by 1e3 to convert unit from w to
   mW
mprintf("\n Threshold optical power level for Raman
    scattering is= %.2f W",Pr);
```

Scilab code Exa 3.4 Critical radius

```


//Optoelectronics and Fiber Optics Communication by
```

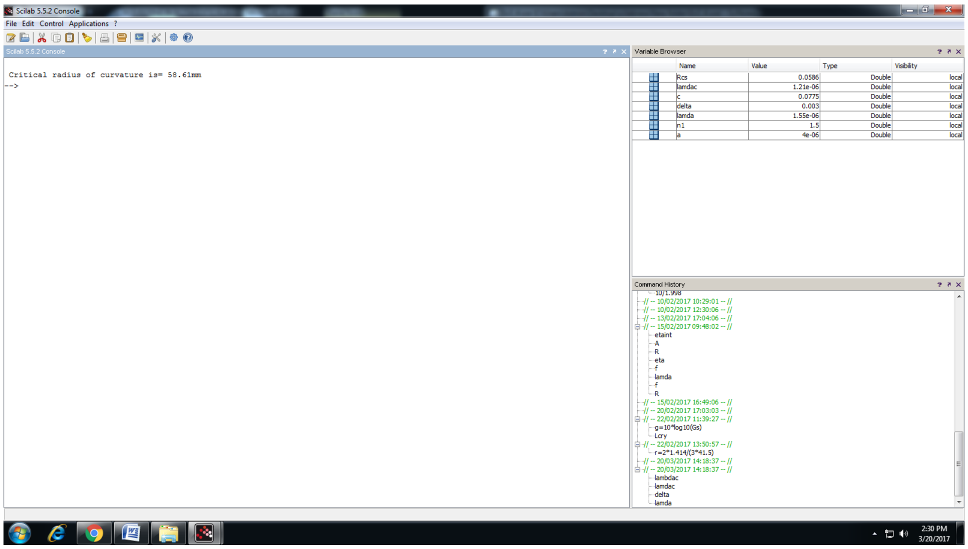

Figure 3.4: Critical radius

```
C.R. Sarkar and D.C. Sarkar
//Example 3.4
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
a=4*10^-6;//radius in m
n1=1.5;//core refractive index
lamda=1.55*10^-6;//operating wavelength in m
delta=0.003;//relative refractive index difference between core and cladding
c=(2*delta)^0.5;//constant value
lamdac=(c*2*%pi*a*n1)/2.405;//cut off wavelength for mono mode
Rcs=(20*lamda)/((delta)^1.5)*((2.748-((0.996)*(lamda/lamdac)))^-3);//critical radius of curvature
mprintf("\n Critical radius of curvature is= %.2fmm"
```

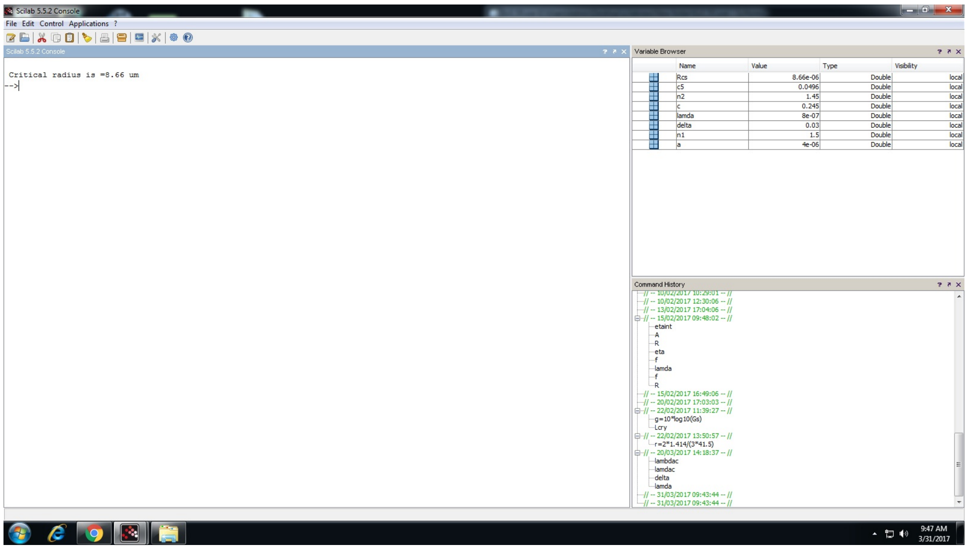

Figure 3.5: critical radius

```
,Rcs*1e3);//multiplication by 1e3 to convert unit
    to mm//the answer given in textbook is wrong
```

Scilab code Exa 3.5 critical radius

```



//Optoelectronics and Fiber Optics Communication by
    C.R. Sarkar and D.C. Sarkar
//Example 3.5
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;
```

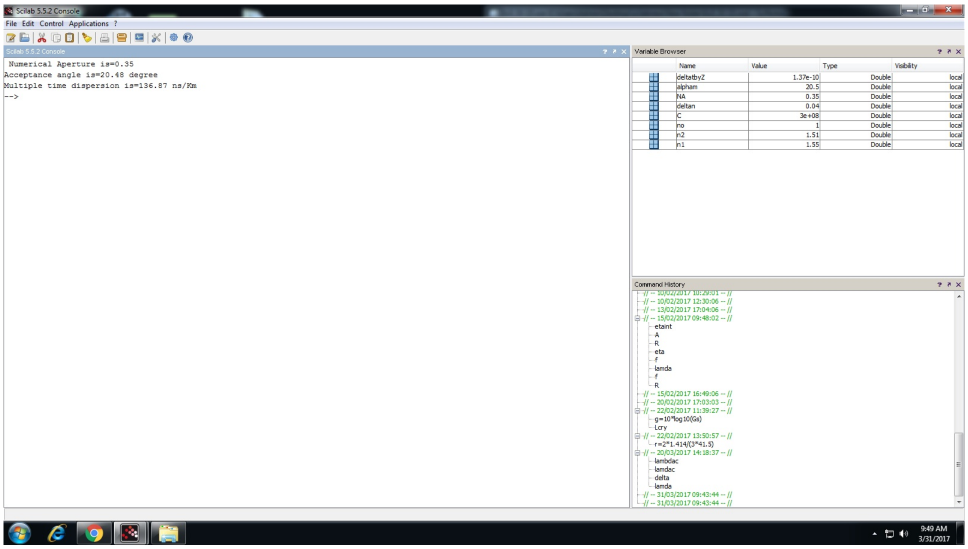

Figure 3.6: NA acceptance angle and multiple time dispersion

```

//given
a=4*10^-6;//radius in m
n1=1.5;//core refractive index
delta=0.03;//delta
lamda=0.80*10^-6;//wavelength in m
c=(2*delta)^0.5;//constant value
n2=sqrt((n1^2)-(2*delta*n1^2));
c5=((n1^2)-(n2^2))^1.5;
Rcs=(3*n1^2*lamda)/(4*%pi*c5);//critical radius
mprintf("\n Critical radius is =%.2f um",Rcs*1e6);//
    multiplication by 1e6 to convert unit to um//the
    answer vary due to rounding
```

Scilab code Exa 3.6 `NA acceptance angle and multiple time dispersion`

```
//Optoelectronics and Fiber Optics Communication by C.R. Sarkar and D.C. Sarkar
//Example 3.6
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given

n1=1.55;//refractive index of core
n2=1.51//refractive index of cladding
no=1//refractive index of air
C=3e8//velocity of light in m/s
deltan=n1-n2;//relative refractive index
NA=((n1+n2)*deltan)^0.5;//Numerical aperture
alpham=asind(NA)//acceptance angle in degrees
deltatbyZ=(n1/n2)*deltan/C//multiple time dispersionin s/m
mprintf("Numerical Aperture is=%.2f",NA);
mprintf("\nAcceptance angle is=%.2f degree",alpham)
mprintf("\nMultiple time dispersion is=%.2f ns/Km",deltatbyZ*1e12)//multiplication by 1e12 to convert unit from s/m to ns/Km
//the answer vary slightly due to rounding
```

Scilab code Exa 3.7 Bandwidth distance product

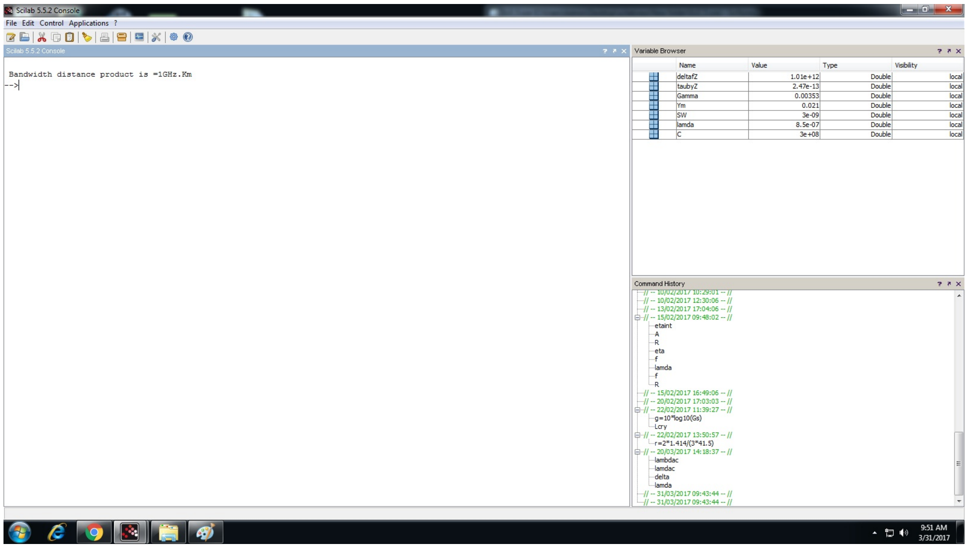

Figure 3.7: Bandwidth distance product

```

//Optoelectronics and Fiber Optics Communication by
    C.R. Sarkar and D.C. Sarkar
//Example 3.7
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
C=3*10^8;//speed of light in m/s
lamda=0.85*10^-6;//wavelength in m
SW=0.003*10^-6;//spectrum width in m
Ym=0.021;//material dispersion parameter (ps/Km.nm)
Gamma=SW/lamda;
taubyZ=(Gamma/C)*(Ym)//in ns/Km
deltafZ=(C)/(4*Gamma*Ym);//Bandwidth distance
    product in GHz.Km
mprintf("\n Bandwidth distance product is =%.0fGHz.
```

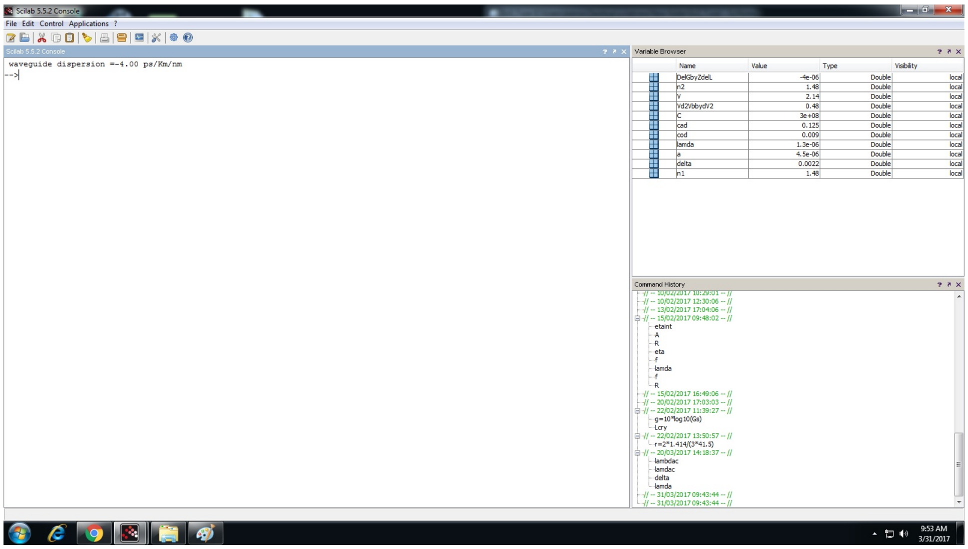

Figure 3.8: Waveguide dispersion

```
Km",deltafZ/1e12);//division by 1e9 to convert
    unit to GHz.Km from Hz.m
```

Scilab code Exa 3.8 `Waveguide dispersion`

```


//Optoelectronics and Fiber Optics Communication by
    C.R. Sarkar and D.C. Sarkar
//Example 3.8
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

```

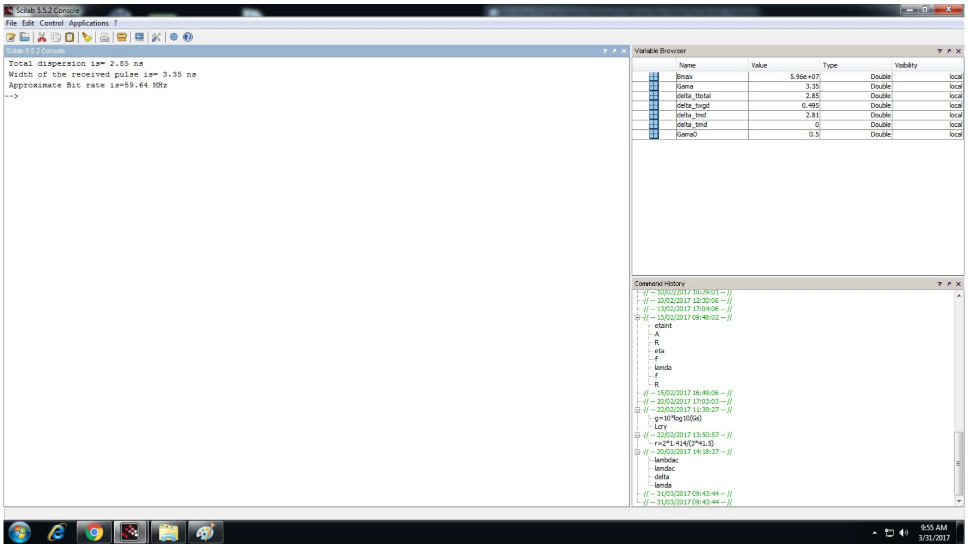

Figure 3.9: Pulse width and approximate bit rate

```
//given
n1=1.48;//refractive index of core
delta=0.0022;//relative refractive index difference
a=4.5*10^-6;//core radius
lamda=1.3*10^-6;//wavelength in m
cod=9*10^-3;//core diameter
cad=125*10^-3;//cladding diameter
C=3e8;//velocity of light in m/s
Vd2VbbydV2=0.48//waveguide dispersion constant at V
    =2.14
V=((2*%pi*a)/lamda)*n1*((2*delta)^0.5);//V-number
n2=n1*(1-delta);
DelGbyZdelL=(-n2*delta)*Vd2VbbydV2/(C*lamda);//
    waveguide dispersion in ps/Km?nm
mprintf("waveguide dispersion =%.2f ps/Km/nm",
    DelGbyZdelL*1e6)//multiplication by 1e6 to
    convert unit ps/Km/nm
```

Scilab code Exa 3.9 `Pulse width and approximate bit rate`

```


//Optoelectronics and Fiber Optics Communication by C.R. Sarkar and D.C. Sarkar
//Example 3.9
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
Gama0=0.5;//transmitted pulse width in ns
delta_timd=0;//total intermodulation dispersion in ns
delta_tmd=2.81;//total material dispersion in ns
delta_twgd=0.495;//total waveguide dispersion in ns
delta_ttotal=((delta_timd^2)+(delta_tmd^2)+(delta_twgd^2))^0.5;//Total dispersion in ns
Gama=Gama0+delta_ttotal;// width of received pulse in ns
Bmax=1/(5*Gama*1e-9);//bitrate in Hz
mprintf("Total dispersion is= %.2f ns",delta_ttotal)
mprintf("\n Width of the received pulse is= %.2f ns",Gama);
mprintf("\n Approximate Bit rate is=%.2f MHz",Bmax/1e6);//division by 1e6 to convert unit into MHz from Hz
```

Chapter 4

Light Emitting Diode LED

Scilab code Exa 4.1 total carrier life time and optical power

```
//Optoelectronics and Fiber Optics Communication by
   C.R. Sarkar and D.C. Sarkar
//Example 4.1
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
h=6.62*10^-34;//Plank's constant in SI units
c=3*10^8;//speed of the light in m/s
e=1.9*10^-19;//electric charge in columb
I=50*10^-3;//drive current in A
lamda=0.85*10^-6;//peak emission wavelength in m
taur=50*10^-9;//radiative carrier life time in s
taunr=100*10^-9;//nonradiative carrier life time in
   s
```

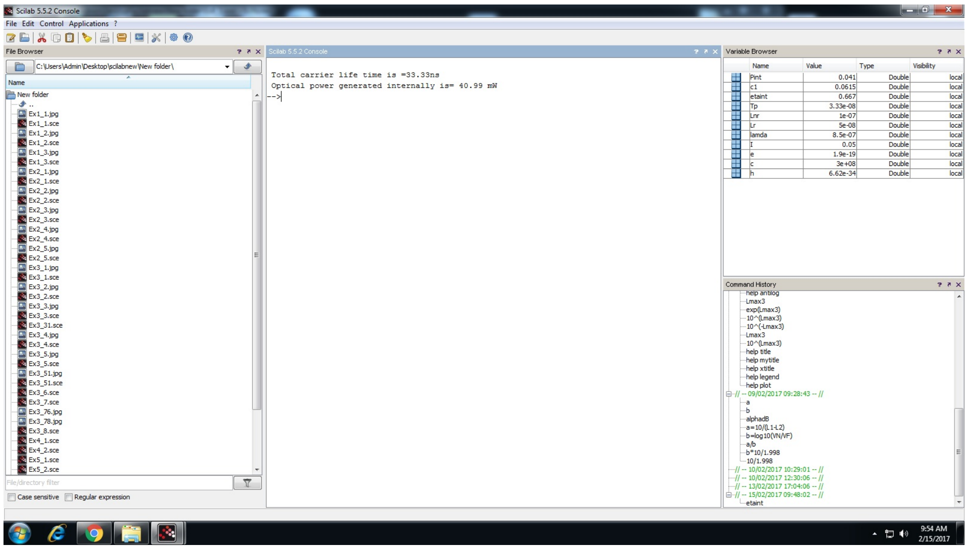

Figure 4.1: total carrier life time and optical power

```
Tp=(taur*taunr)/(taur+taunr);///total carrier life
    time in s
etaint=Tp/taur;//equation of internal efficiency
c1=(I*h*c)/(e*lamda);//constant value
Pint=(etaint)*c1;//internal optical power generated
    in W
mprintf("\n Total carrier life time is =%.2fns ",Tp
    *1e9);//multiplication by 1e9 for conversion of
    unit from s to ns
mprintf("\n Optical power generated internally is= %
    .2f mW ",Pint*1e3);//multiplication by 1e3 for
    conversion of unit from W to mW//the answer vary
    due to rounding
```

Scilab code Exa 4.2 optical power coupled

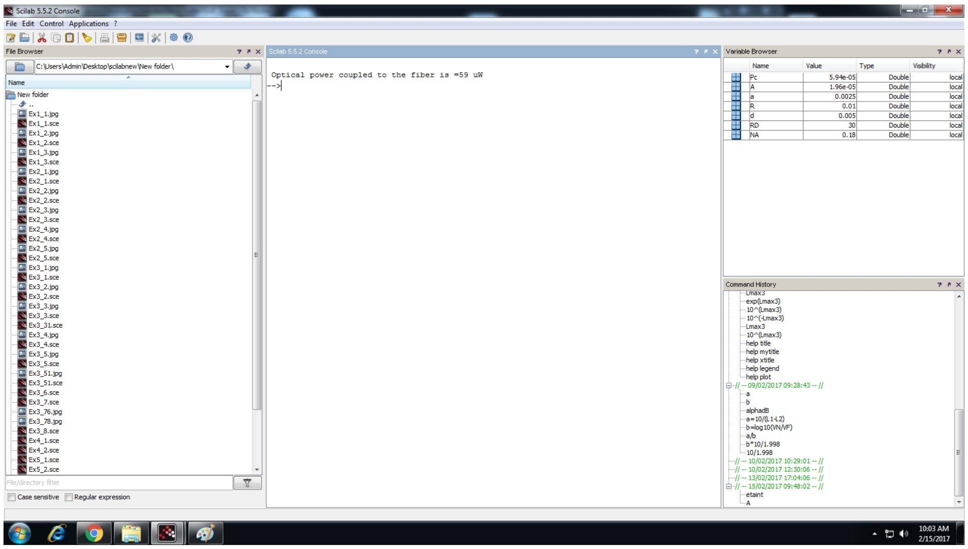

Figure 4.2: optical power coupled

```

//Optoelectronics and Fiber Optics Communication by C.R. Sarkar and D.C. Sarkar
//Example 4.2
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
NA=0.18;//numerical aperture
RD=30;//radiance of the source in W/Sr/cm^2
d=50*10^-4;//core diameter in cm
R=0.01;//Fresnel reflection coefficient
a=d/2;//radius of the core in cm
A=%pi*((a)^2);//emission area of the source in cm^2
Pc=%pi*(1-R)*A*RD*((NA)^2);//optical power coupled to the fiber in W
mprintf("\n Optical power coupled to the fiber is =%
```

```
.0f uW",Pc*1e6);//multiplication by 1e6 for
conversion of unit from W to uW//the answer given
 in textbook is wrong
```

Chapter 5

Semiconductor Lasers

Scilab code Exa 5.1 ratio between stimulated and spontaneous emission rate

```


//OptoElectronics and Fibre Optics Communication, by C.K Sarkar and B.C Sarkar
//Example 5.1
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
Tc=727;//temperature in celcius
lamda=0.5*10^-6;//wavength of emitting radiation in M
h=6.626*10^-34;//Plank's constant in SI units
KB=1.38*10^-23;//boltzman constant in SI units
c=3*10^8;//speed of light in m/s
f=c/lamda;//frequency in Hz
T=Tc+273;//temperature in kelvin
```

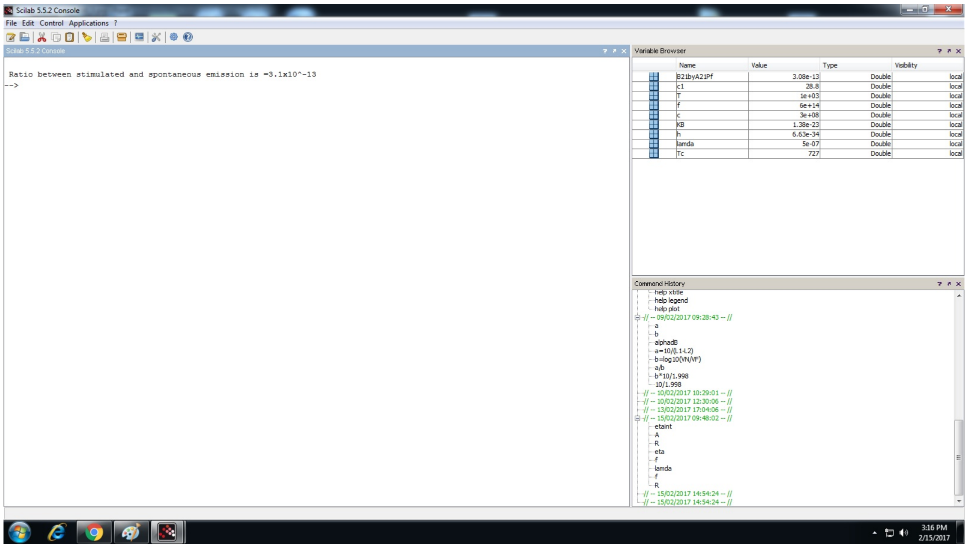

Figure 5.1: ratio between stimulated and spontaneous emission rate

```
c1=(h*f)/(KB*T);//constant value
B21byA21Pf=1/(exp(c1)-1);//ratio of stimulated and spontaneous emission rate
mprintf("\n Ratio between stimulated and spontaneous emission is =%.1fx10^-13",B21byA21Pf*1e13); //multiplication by 1e13 to convert the ratio to 10^-13
```

Scilab code Exa 5.2 `Threshold current Density`

```


//OptoElectronics and Fibre Optics Communication, by C.K Sarkar and B.C Sarkar
//Example 5.2
//OS=Windows 10
```

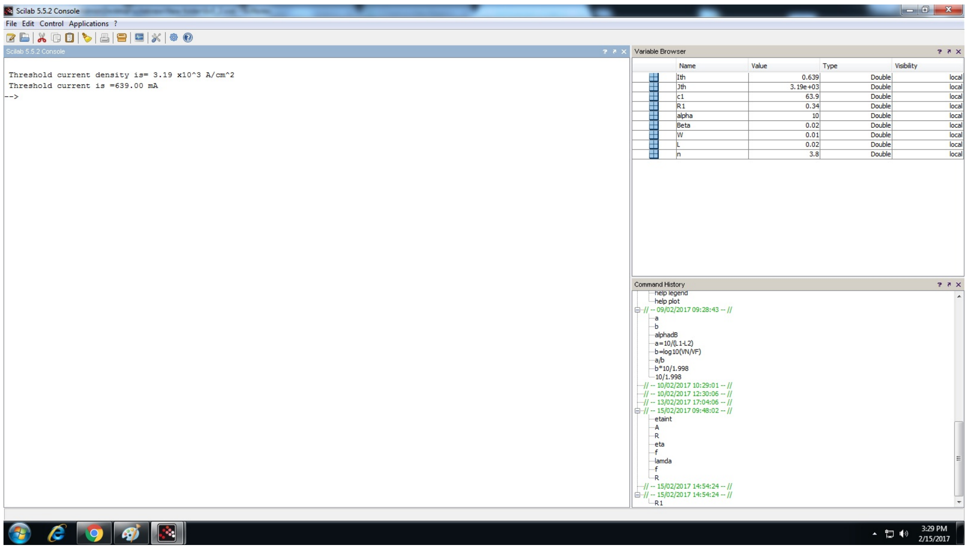

Figure 5.2: Threshold current Density

```
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
n=3.8;//refractive index
L=200*10^-4;//length in cm
W=100*10^-4;//width in cm
Beta=20*10^-3;//gain factor in A/cm^3
alpha=10;//loss coefficient per cm
R1=((n-1)/(n+1))^2;//reflectivity
c1=((alpha+((1/L)*(log(1/R1)))))//constant value
Jth=(1/Beta)*c1;//threshold current density in A/cm
    ^2
mprintf("\n Threshold current density is= %.2f x10^3
    A/cm^2",Jth*1e-3);//multiplication by 1e-3 to
    convert the ratio to 10^-3
Ith=Jth*L*W;//threshold current in A
mprintf("\n Threshold current is =%.2f mA",Ith*1e3);
    //the answer vary due to rouding
```

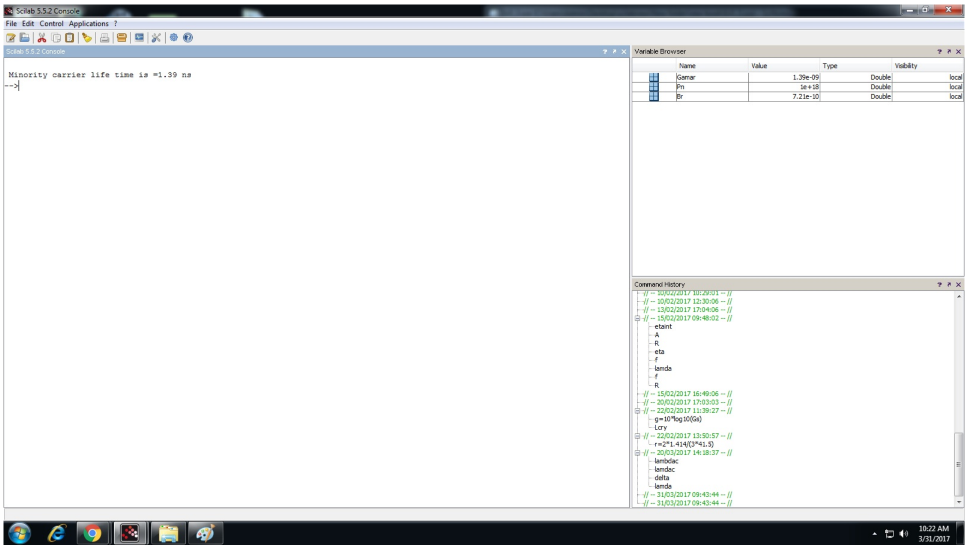

Figure 5.3: minority carrier life time

Scilab code Exa 5.3 `minority carrier life time`

```

//OptoElectronics and Fibre Optics Communication, by C.K Sarkar and B.C Sarkar
//Example 5.3
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
Br=7.21*10^-10;//injected electron density
Pn=10^18;//majority carrier hole density in/cm^3
Gamar=1/(Br*Pn);//minority carrier life time
```

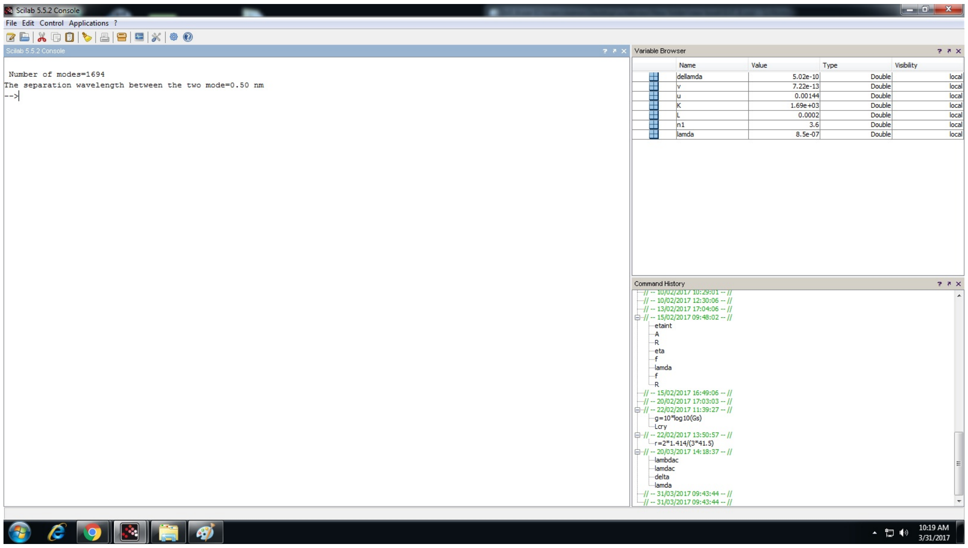

Figure 5.4: number of longitudinal modes

```
mprintf("\n Minority carrier life time is =%.2f ns "
    ,Gamar*1e9);// the answer vary due to roundingoff
//multiplication by 1e9 to convert the unit to nm
```

Scilab code Exa 5.4 `number of longitudinal modes`

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 5.5
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
```

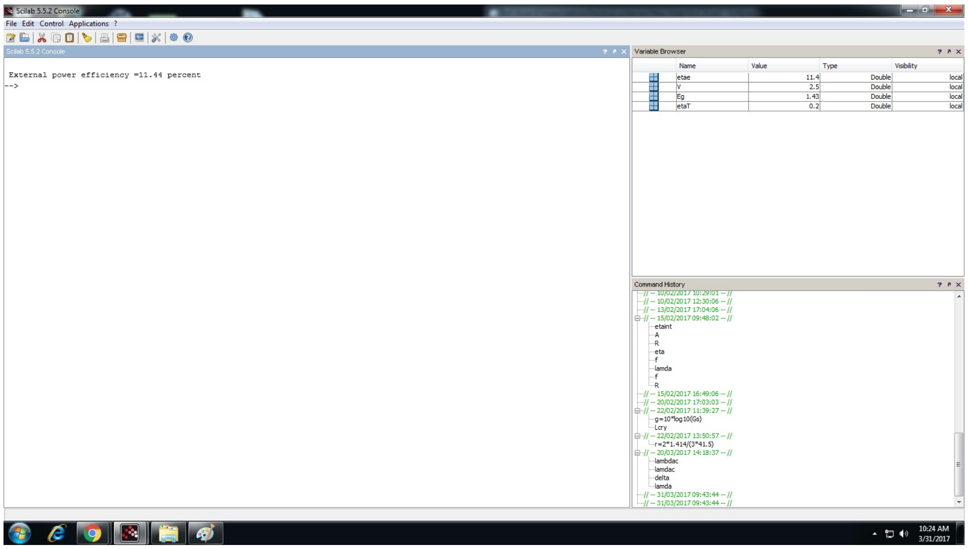

Figure 5.5: External Power efficiency

```
lamda=0.85*1e-6;//wavelength of GaAs in m
n1=3.6;//refractive index
L=200e-6//length of the cavity in m
K=L*(2*n1)/lamda;//number of modes
mprintf("\n Number of modes=%.0f ",K);//the answer vary due to rounding//multiplication by 1e6 to convert the unit to um
u=2*n1*L;//partial product
v=(lamda)^2;//partial product
dellamda=v/u;//separation wavelength between the two mode in m
mprintf("\nThe separation wavelength between the two mode=%.2f nm",dellamda*1e9);//multiplication by 1e9 to convert the unit to nm// the answer given in textbook is wrong the unit is nm but the textbook gives it as um
```

Scilab code Exa 5.5.A External Power efficiency

```
//OptoElectronics and Fibre Optics Communication , by
    C.K Sarkar and B.C Sarkar
//Example 5.5(A)
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
etaT=0.20//total efficiency
Eg=1.43//bandgap energy in eV
V=2.5//applied voltage in V
etae=etaT*Eg*100/V//external power efficiency
mprintf("\n External power efficiency =%.2f percent
  ",etae);
```

Scilab code Exa 5.5 External Power efficiency

```
//OptoElectronics and Fibre Optics Communication , by
    C.K Sarkar and B.C Sarkar
//Example 5.5
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

```

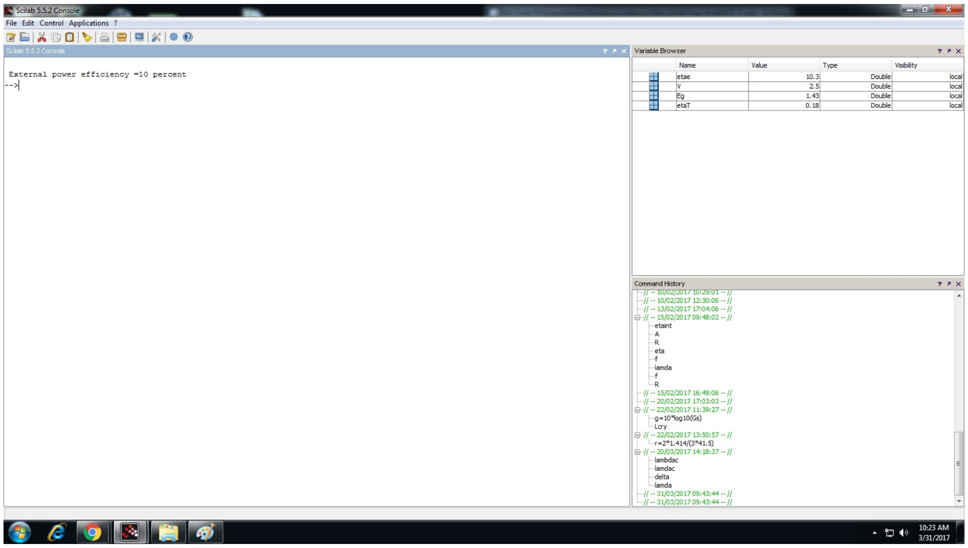

Figure 5.6: External Power efficiency

```
//given
etaT=0.18//total efficiency
Eg=1.43//bandgap energy in eV
V=2.5//applied voltage in V
etae=etaT*Eg*100/V//external power efficiency
mprintf("\n External power efficiency =%.0f percent
   ",etae);
```

Scilab code Exa 5.6 `Threshold current densities`

```

//OptoElectronics and Fibre Optics Communication, by
   C.K Sarkar and B.C Sarkar
//Example 5.6
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
```

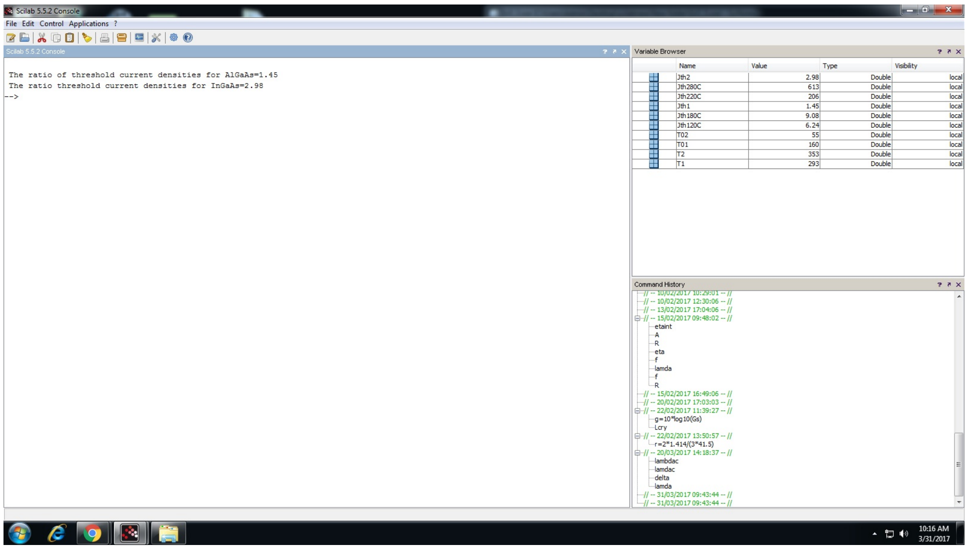

Figure 5.7: Threshold current densities

```
clc;
clear;

//given
T1=273+20;//first temperature for an AlGaAs injection laser diode in kelvin
T2=273+80;//second temperature for an AlGaAs injection laser diode in kelvin
T01=160;//first thershold temperature in kelvin
T02=55;//second thershold temperature in kelvin;

//case 1:
Jth120C=exp(T1/T01);
Jth180C=exp(T2/T01);
Jth1=Jth180C/Jth120C;
mprintf("\n The ratio of threshold current densities for AlGaAs=%.2f",Jth1);//the answer vary due to rounding

//case 2:
```

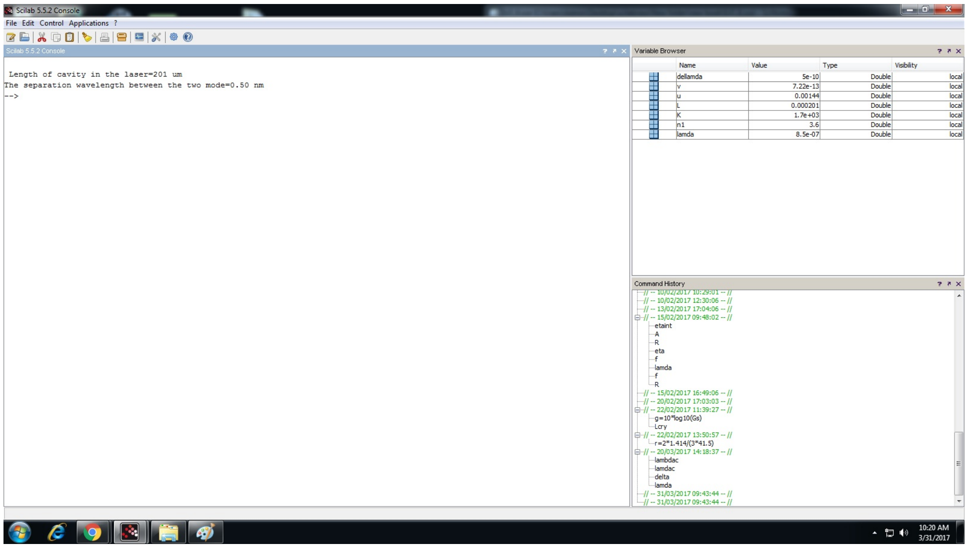

Figure 5.8: length of cavity in laser and wavelength separation

```
Jth220C=exp(T1/T02);
Jth280C=exp(T2/T02);
Jth2=Jth280C/Jth220C;
mprintf("\n The ratio threshold current densities
    for InGaAs=%.2f",Jth2);
```

Scilab code Exa 5.7 length of cavity in laser and wavelength separation

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 5.7
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;
```

```

//given
lamda=0.85*1e-6;//wavelength of GaAs in m
n1=3.6;//refractive index
K=1700//number of modes
L=K*lamda/(2*n1);//length of the cavity in m
mprintf("\n Length of cavity in the laser=%.0f um",L*1e6);//the answer vary due to rounding//multiplication by 1e6 to convert the unit to um
u=2*n1*L;//partial product
v=(lamda)^2;//partial product
dellamda=v/u;//separation wavelength between the two mode in m
mprintf("\nThe separation wavelength between the two mode=%.2f nm",dellamda*1e9);//multiplication by 1e9 to convert the unit to nm// the answer given in textbook is wrong the unit is nm but the textbook gives it as um
```

Chapter 6

Photo Detectors

Scilab code Exa 6.1 opearting wavelength and incident power

```
//Optoelectronics and Fiber Optics Communication by
    C.R. Sarkar and D.C. Sarkar
//Example 6.1
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
eta=0.70;//quantum efficiency
E=2.2*10^-19;//energy of the photons in Joule
Ip=2*10^-6;//photocurrent in A //the value in
    question is different from that used in solution
    in question it is mA and in solution it is uA
h=6.62*10^-34;//Planck's constant in SI units
c=3*10^8;//speed of the light in m/s
e=1.9*10^-19;//electric charge in coulomb
```

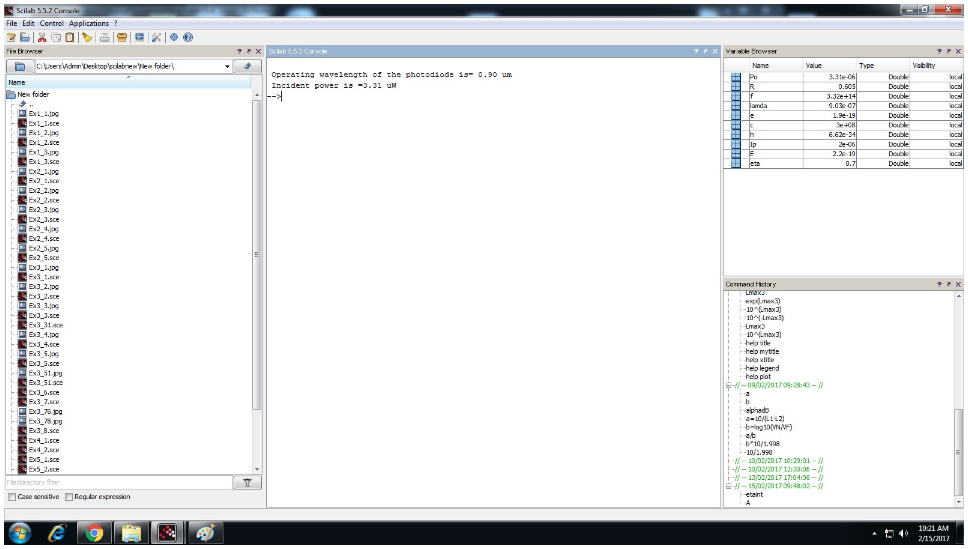

Figure 6.1: opearting wavelength and incident power

```
lamda=(h*c)/E;//operating wavelength of the photodiode in m
f=c/lamda;//frequency in Hz
R=(eta*e)/(h*f);//Responsivity in A/W
Po=Ip/R;//incident power in W
mprintf("\n Operating wavelength of the photodiode is= %.2f um",lamda*1e6);//multiplication by 1e6 for conversion of unit from m to um
mprintf("\n Incident power is =%.2f uW",Po*1e6);//multiplication by 1e6 for conversion of unit from W to uW
```

Scilab code Exa 6.2 quantum efficiency and reponsivity

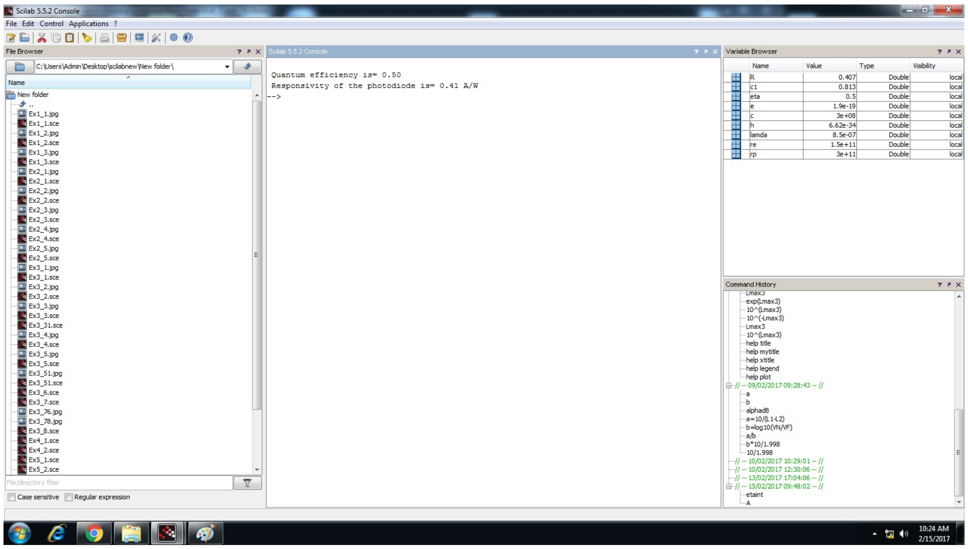

Figure 6.2: quantum efficiency and reponsivity

```
//Optoelectronics and Fiber Optics Communication by
   C.R. Sarkar and D.C. Sarkar
//Example 6.2
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
rp=3*10^11;//number of incident photon
re=1.5*10^11;//number of hole-pairs generated
lamda=0.85*10^-6;//wavength in m
h=6.62*10^-34;//Plank's constant in SI Unit
c=3*10^8;//speed of the light in m/s
e=1.9*10^-19;//electric charge in Coulomb
eta=re/rp;//quantum efficiency
c1=(e*lamda)/(h*c);//constant value
R=eta*c1;//responsivity of the photodiode inA/W
mprintf("\n Quantum efficiency is= %.2f",eta);
```

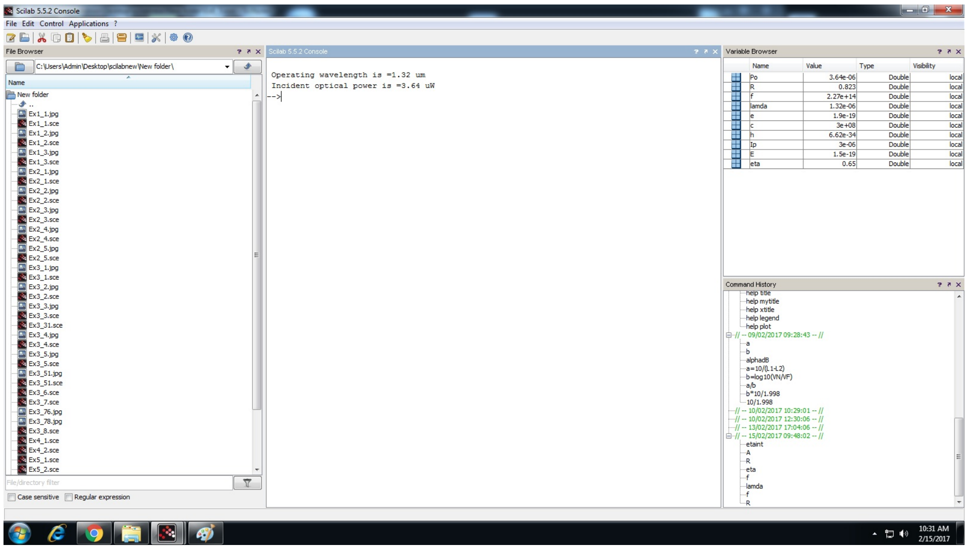

Figure 6.3: wavelength and incident optical power

```
mprintf("\n Responsivity of the photodiode is= %.2f
    A/W",R);
```

Scilab code Exa 6.3 `wavelength and incident optical power`

```

//Optoelectronics and Fiber Optics Communication by
    C.R. Sarkar and D.C. Sarkar
//Example 6.3
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
```

```
eta=0.65;//quantum efficiency
E=1.5*10^-19;//energy of the photons in V
Ip=3*10^-6;//diode current in A
h=6.62*10^-34;//Plank's constant in SI unit
c=3*10^8;//speed of the light in m/s
e=1.9*10^-19;//electric charge in coulomb
lamda=(h*c)/E;//wavelengthof the operating diode in
   m
f=c/lamda;//frequency in Hz
R=(eta*e)/(h*f);//responsivity in A/W
Po=Ip/R;//incident optical power in W
mprintf("\n Operating wavelength is =%.2f um",lamda
   *1e6);//multiplication by 1e6 for conversion of
   unit from m to um
mprintf("\n Incident optical power is =%.2f uW ",Po
   *1e6);//multiplication by 1e6 for conversion of
   unit from W to uW//the answer vary due to
   rounding
```

Scilab code Exa 6.4 critical frequency

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 6.4
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
Eg1=1.43;//Band Gap Energy of photodetector in eV
Eg2=[(1.43*1.6*10^-19)];//Band Gap Energy in joule
```

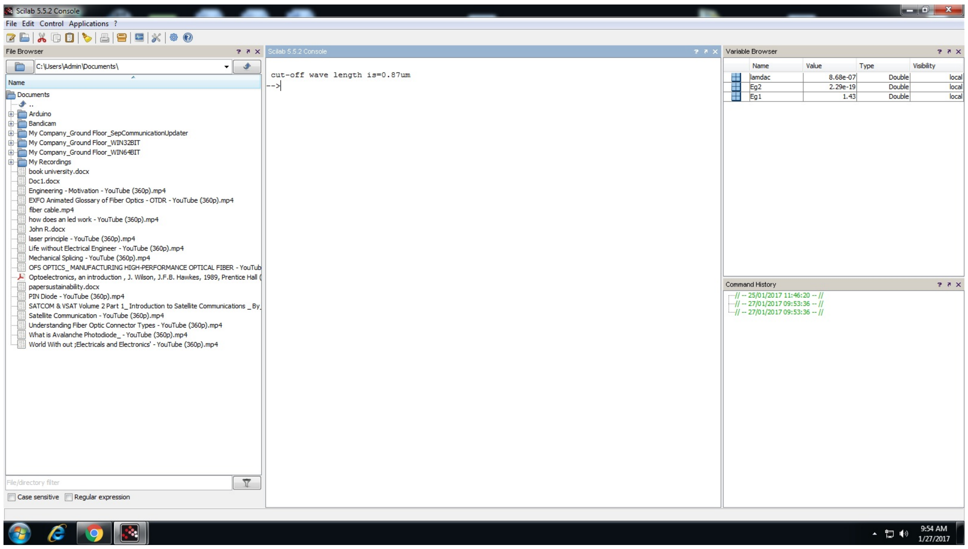

Figure 6.4: critical frequency

```

lamdac=[(6.62*10^-34*3*10^8)/Eg2];//Cut-Off wave length in micrometer
mprintf("\n cut-off wave length is=%.2fum",lamdac*10^6);//multiplication by 10^6 to convert unit into um//the error is due to roundingoff
```

Scilab code Exa 6.5 `Fraction of incident power`

```

//OptoElectronics and Fibre Optics Communication, by C.K Sarkar and B.C Sarkar
//Example 6.5
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
```

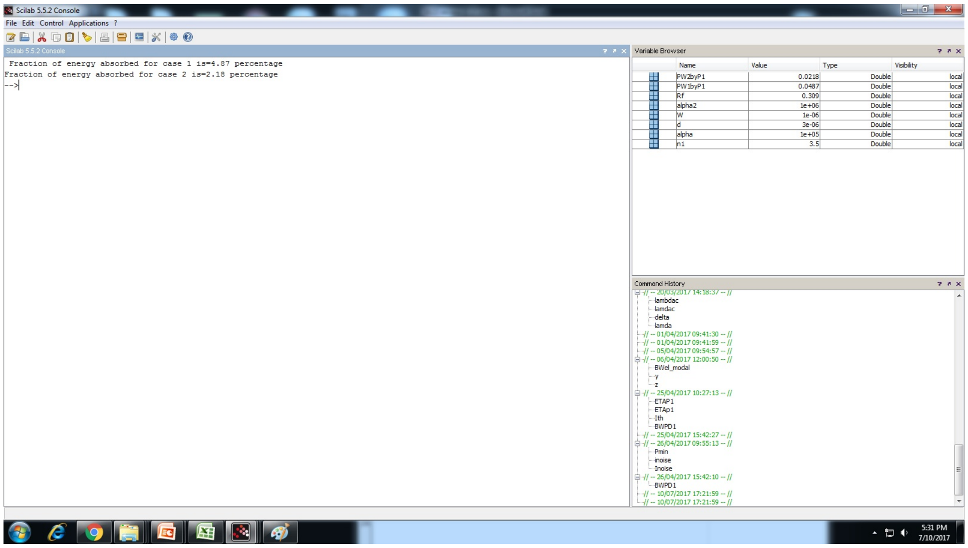

Figure 6.5: Fraction of incident power

```
clear;

//given
//case (1):
n1=3.5;//refractive index of layer 1
alpha=1e5;//it is in m^-1
d=3e-6//depth of planar layer in m
W=1e-6//width of depletion layer in m
//case (2):
alpha2=1e6;//it is in 1/m

Rf=[(n1-1)/(n1+1)]^2;//reflection coefficient
//case (1):
PW1byP1=exp(-alpha*(d))*[1-exp(-alpha*W)]*(1-Rf);//
    fraction of incident power absorbed
//case (2):
PW2byP1=[exp(-alpha2*(d))]*[1-exp(-alpha2*W)]*(1-Rf)
    ;//fraction of incident power absorbed
mprintf("Fraction of energy absorbed for case 1 is=
    %0.2f percentage",PW1byP1*100);
```

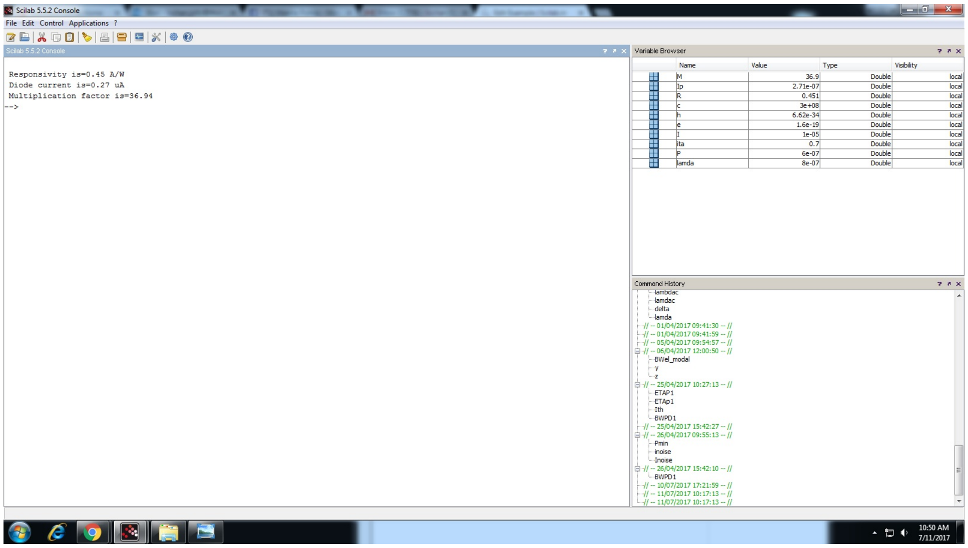

Figure 6.6: Multiplication factor

```
mprintf("\nFraction of energy absorbed for case 2 is
    =%0.2f percentage",PW2byP1*100);
```

Scilab code Exa 6.6 `Multiplication factor`

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 6.6
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
```

```
lamda=0.8e-6;//wave length of radiation in micrometer
P=0.60e-6;//optical power in microwatts
ita=0.7;//quantum efficiency of a silicon RAPD is 70 %
I=10e-6;//Output of device after avalanche gain in microampere
e=1.6e-19;//
h=6.62e-34;//plank's constant in S.I units
c=3e8;//velocity of light in m/s

R=[(ita*e*lamda)]/[h*c];//Responsivity in A/W
Ip=P*R;//diode current in microampere
M=I/Ip;//multiplication factor
mprintf("\n Responsivity is=%.2f A/W",R);
mprintf("\n Diode current is=%.2f uA",Ip*1e6);//multiplication by 1e6 to convert the unit from ampers to uA
mprintf("\n Multiplication factor is=%.2f",M);
```

Scilab code Exa 6.7 noise equivalent power and specific directivity

```

//OptoElectronics and Fibre Optics Communication, by C.K Sarkar and B.C Sarkar
//Example 6.7
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
A=(100)*(50);//area in u-meter^2
```

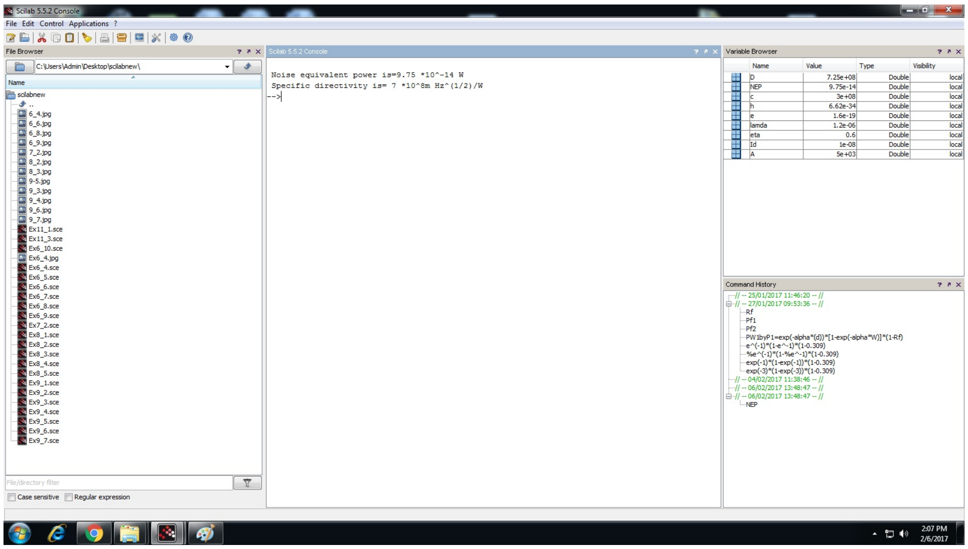

Figure 6.7: noise equivalent power and specific directivity

```
Id=10e-9;//Measured dark current in nanoampere
eta=0.6;//Quantum efficiency is 60%
lamda=1.2e-6;//operating wave length in micrometer
e=1.6e-19;//charge of an electron in columb
h=6.62e-34;//plank's constant in S.I units
c=3e8;//velocity of light in m/s

NEP=[h*c*sqrt(2*e*Id)]/(eta*e*lamda);//noise equivalent power in watts
D=sqrt(A*10^-12)/(NEP);//Specific directivity of the device
mprintf("\n Noise equivalent power is=%.2f *10^-14 W",NEP*10^14);//multiplication by10^-14 to change the unit 10^-14 W
mprintf("\n Specific directivity is=%2.f *10^8m Hz^(1/2)/W",D/10^8)//multiplication by10^8 to change the unit 10^8 m Hz^(1/2)/W
```

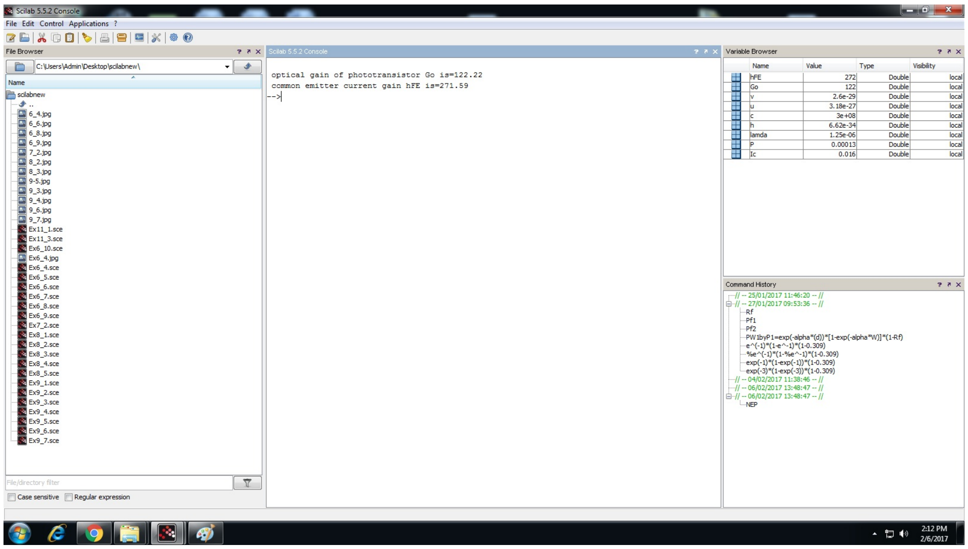

Figure 6.8: optical gain and current gain

Scilab code Exa 6.8 `optical gain and current gain`

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 6.8
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
Ic=16e-3;//collector current in mA
P=130e-6;//incident power in microwatts
lamda=1.25e-6;//wavelength in micrometer
h=6.62e-34;//plank's constant in S.I units
c=3e8;//velocity of light in m/s
```

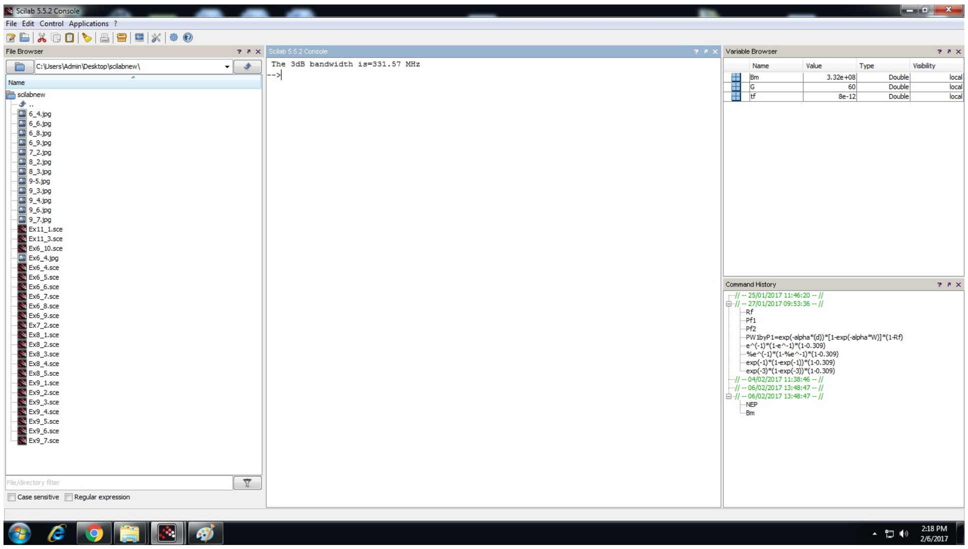

Figure 6.9: Bandwidth

```

//case 1:
u=h*c*Ic;
v=lamda*P*1.6e-19;
Go=u/v;//optical gain of the photo transistor
//case 2:
hFE=Go/0.45;//common emitter current gain
mprintf("\n optical gain of phototransistor Go is=%
    .2f",Go);
mprintf("\n common emitter current gain hFE is=%.2f"
    ,hFE);
//Answers are different due to roundingoff error
```

Scilab code Exa 6.9 Bandwidth

```

```

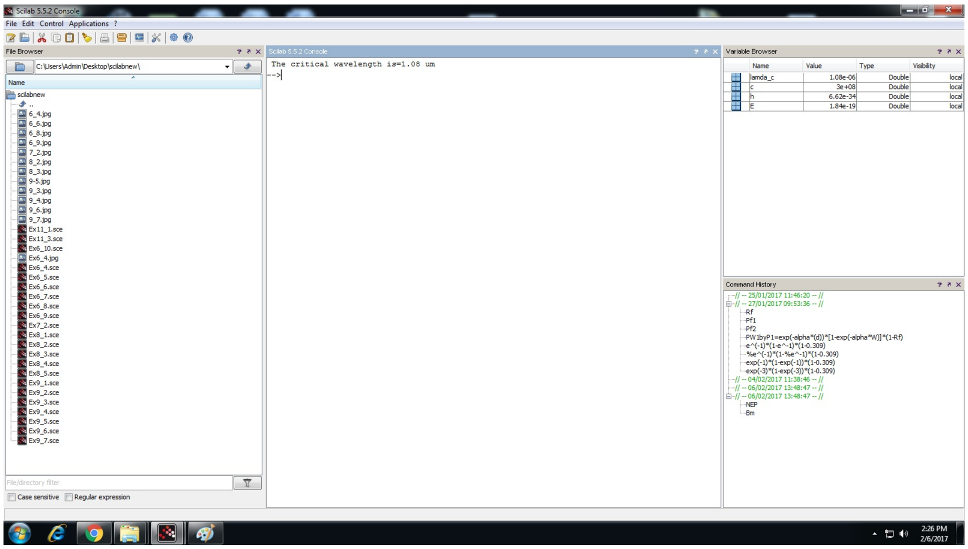

Figure 6.10: critical wavelength

```
//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 6.9
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
tf=8e-12;//electron transit time in second
G=60//photoconductive gain of the device

Bm=1/(2*%pi*tf*G);//the maximum 3dB bandwidth in Hz
mprintf("The 3dB bandwidth is=%.2f MHz",Bm/1e6);//
    division by 1e6 to covert unit from Hz to MHz
//The answer in textbook is wrong
```

Scilab code Exa 6.10 critical wavelength

```
//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 6.10
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
E=1.15*(1.6e-19);//band gap energy in V
h=6.62e-34;//plank's constant in S.I units
c=3e8;//velocity of light in m/s


lamda_c=(h*c)/(E);//critical wavelength in meter
mprintf("The critical wavelength is=%.2f um",lamda_c
   *1e6);//multiplication by 1e6 to convert unit
   from m to um
//the answer vary due to roundingoff
```

Scilab code Exa 6.11 conversion efficiency

```
//Optoelectronics and Fiber Optics Communication by
   C.R. Sarkar and D.C. Sarkar
//Example 6.11
//OS = Windows 7
```

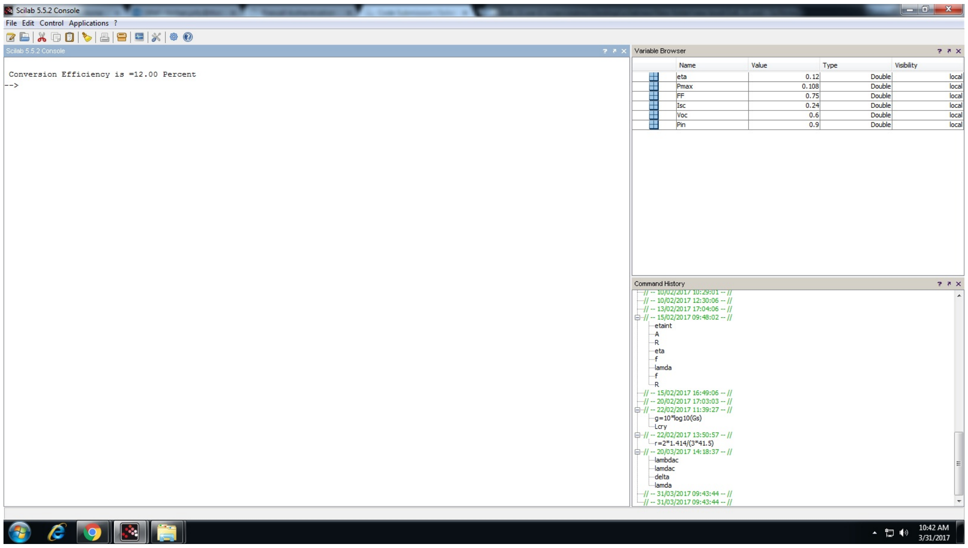

Figure 6.11: conversion efficiency

```
//Scilab version 5.5.2

clc;
clear;

//given
Pin=900*10^-3;// Input Power in W
Voc=600*10^-3;// Open circuit voltage in V
Isc=240*10^-3;//Short circuit current in A
FF=0.75;//Fill factor
Pmax=(Voc*Isc*FF);// Maximum Power in W
eta=(Pmax/Pin);// Conversion Efficiency
mprintf("\n Conversion Efficiency is =%.2f Percent",
    eta*100);//multiplication by 100 to convert into
    percentage
```

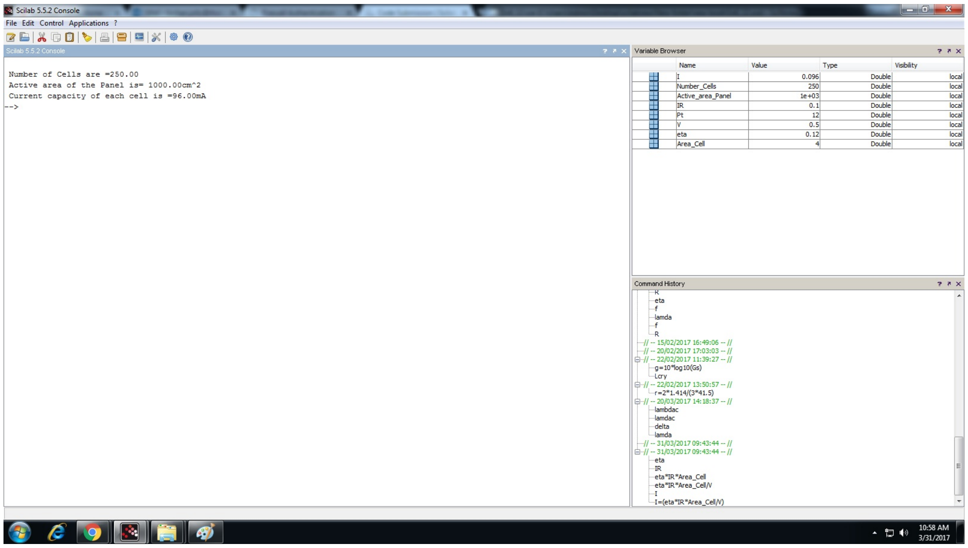

Figure 6.12: number of cells total area of panel and current capacity of each cell

Scilab code Exa 6.12 `number of cells total area of panel and current capacity of e`

```
//Optoelectronics and Fiber Optics Communication by
   C.R. Sarkar and D.C. Sarkar
//Example 6.12
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
Area_Cell=4;// Area of each cell in cm^2
eta=0.12;// Conversion Efficiency
V=0.5;// Voltage generated in V
Pt=12;// Total output Power in W
IR=100*10^-3;// Solar Constant or Input Radiation in
    mW/cm^2
```

```
Active_area_Panel=(Pt/(IR*eta));// Active area of the Panel in cm^2
Number_Cells=(Active_area_Panel/Area_Cell);// Number of cells
I=(eta*IR*Area_Cell/V);// Current capacity in A
mprintf("\n Number of Cells are =%.2f",Number_Cells);
mprintf("\n Active area of the Panel is= %.2fcm^2",Active_area_Panel);
mprintf("\n Current capacity of each cell is =%.2fmA",I*1e3);//Multiplication by 1e3 to convert unit to mA from A
```

Chapter 7

Manufacture of fibers and cables

Scilab code Exa 7.1 `value of n`

```

//Optoelectronics and Fiber Optics Communication by
    C.R. Sarkar and D.C. Sarkar
//Example 7.1
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
theta=30;//value of angle of deliverence in degrees
b=cosd(theta);// cosine value of the theta
a=log10(b);//constant
c=log10(1/2);//constant
n=c/a;//  refractive index
mprintf("The value of refractive index is= %.2f",n);
```

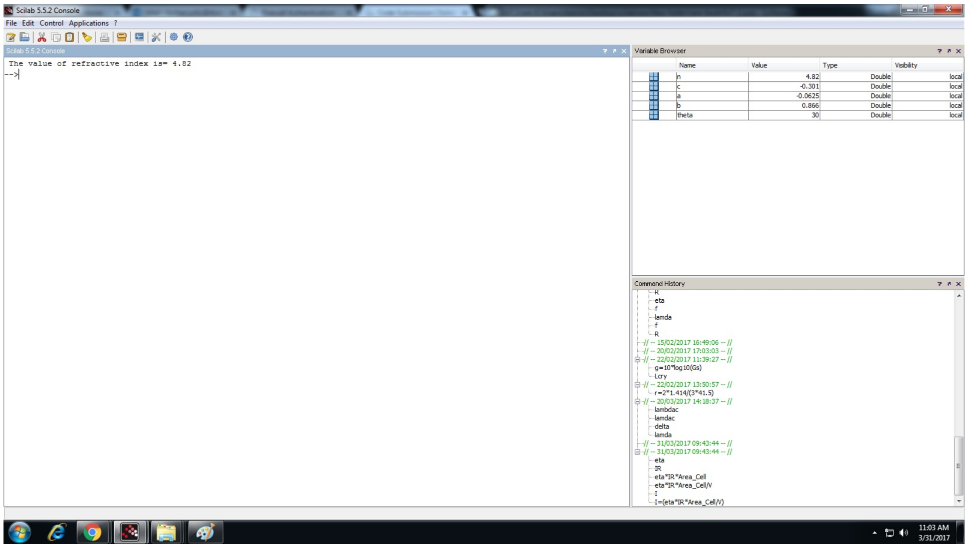

Figure 7.1: value of n

```
//the answer vary due to rounding
```

Scilab code Exa 7.2 `Lateral power distribution coefficient`

```

//Optoelectronics and Fiber Optics Communication by C.R. Sarkar and D.C. Sarkar
//Example 7.2
//OS = Windows 7
//Scilab version 5.5.2

clc;
clear;

//given
theta=10;// value of theta in degrees
```

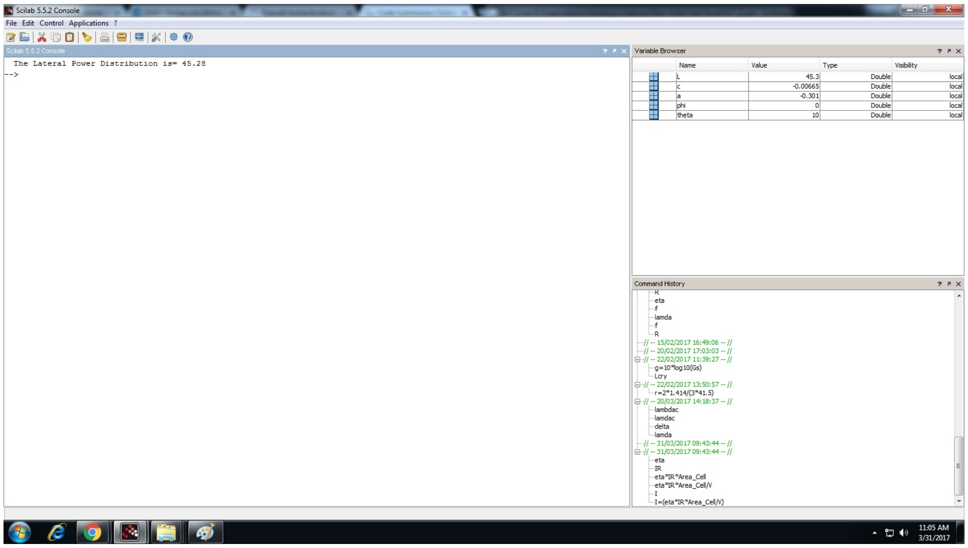

Figure 7.2: Lateral power distribution coefficient

```
phi=0;// value of phi in degrees
a=log10(1/2);// value of constant
c=log10(cosd(theta));// constant
L=a/c;// lateral power distribution
mprintf(" The Lateral Power Distribution is= %.2f",L
   );//the answer vary due to rounding
```

Scilab code Exa 7.3 `maximum magnification factor and coupling efficiency`

```

//Optoelectronics and Fiber Optics Communication by
   C.R. Sarkar and D.C. Sarkar
//Example 7.3
//OS = Windows 7
//Scilab version 5.5.2

```

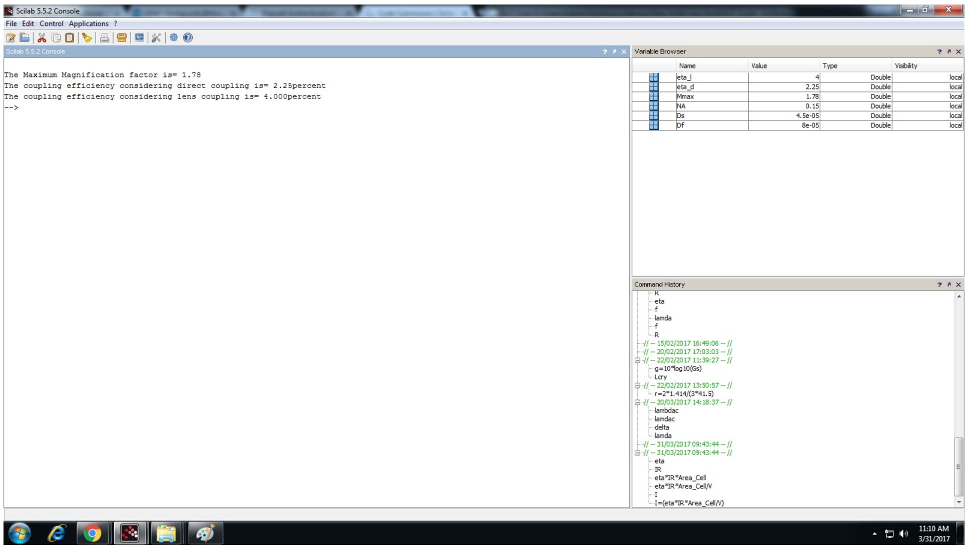

Figure 7.3: maximum magnification factor and coupling efficiency

```
clc;
clear;

//given
Df=80*10^-6;// diameter of the fiber in m
Ds=45*10^-6;// diameter of the source in m
NA=0.15;// numerical aperture of the fiber
Mmax=(Df/Ds);// maximum magnification
eta_d=((NA)^2)*100;// coupling efficiency
    considering direct coupling
eta_l=((Mmax)*(NA^2))*100;// coupling efficiency
    considering lens coupling
mprintf("\nThe Maximum Magnification factor is= %.2f
    ",Mmax);
mprintf("\nThe coupling efficiency considering
    direct coupling is= %.2fpercent",eta_d);
mprintf("\nThe coupling efficiency considering lens
    coupling is= %.3fpercent",eta_l);//the answer
    vary due to rounding
```

Chapter 8

Optical Fiber receiver

Scilab code Exa 8.1 `photocurrent shot noise and thermal noise`

```
//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 8.1
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
eta=0.50;//quantum efficiency of optical fibre
e=1.6e-19;//energy of electron in 1 joules
Po=250e-9;//incident optical power in watts
B=8e6;//bandwidth of receiver in Hz
lamda=0.85e-6;//wavelenth in meter
Id=4e-9;//dark current in ampere
t=300;//temperature in kelvin
c=3e8;// velocity in m/s
K=1.38e-23;//bolt'zman constant in S.I units
```

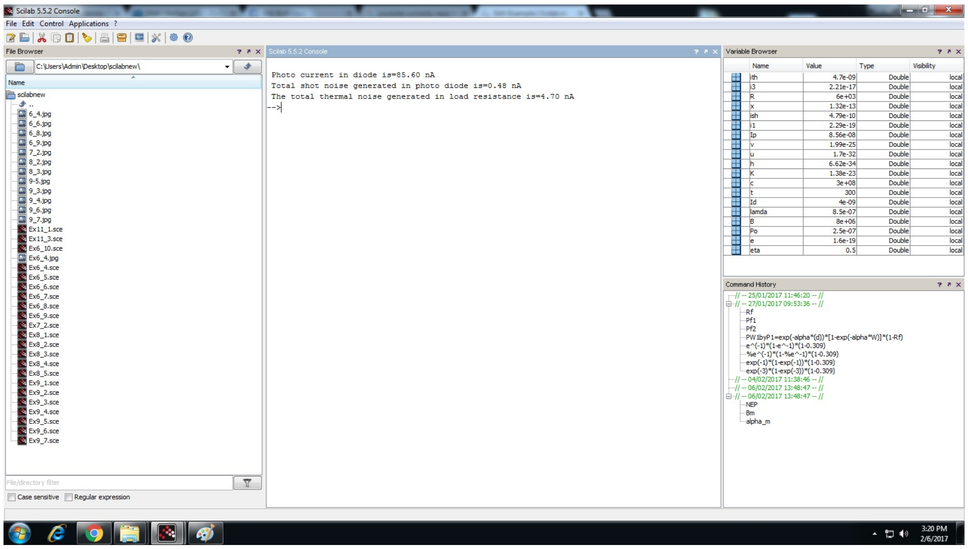

Figure 8.1: photocurrent shot noise and thermal noise

```
h=6.62e-34//planck's constant in S.I.Units
//case 1:
u=[eta*e*Po*lamda];
v=[h]*[c];
Ip=u/v;//photo current in diode in nA
mprintf("\n Photo current in diode is=%.2f nA",Ip*1
    e9);

//case 2:
i1=2*e*B*(Ip+Id);
ish=sqrt(i1);//total shot noise generated in photo
    diode
mprintf("\n Total shot noise generated in photo
    diode is=%.2f nA",ish*1e9);

//case 3:
x=4*K*t*B;
R=6e3;//load resistance in ohms
i3=x/R;
ith=sqrt(i3);//total thermal noise generated in load
```

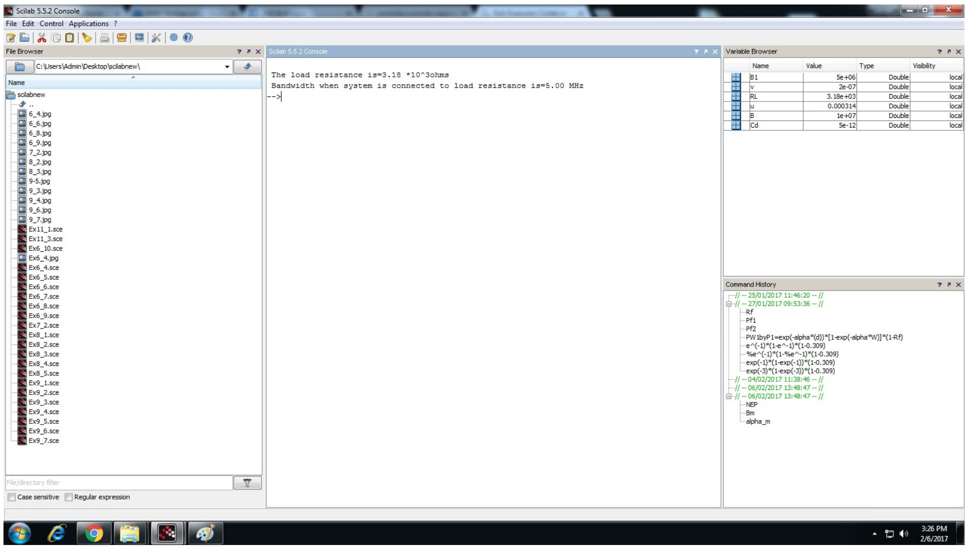

Figure 8.2: maximum load resistance

```
    resistance
mprintf("\n The total thermal noise generated in
   load resistance is=%.2f nA",ith*1e9);
 //multiplication by 1e9 to convert the unit from A
    to nA
```

Scilab code Exa 8.2 `maximum load resistance`

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 8.2
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;
```

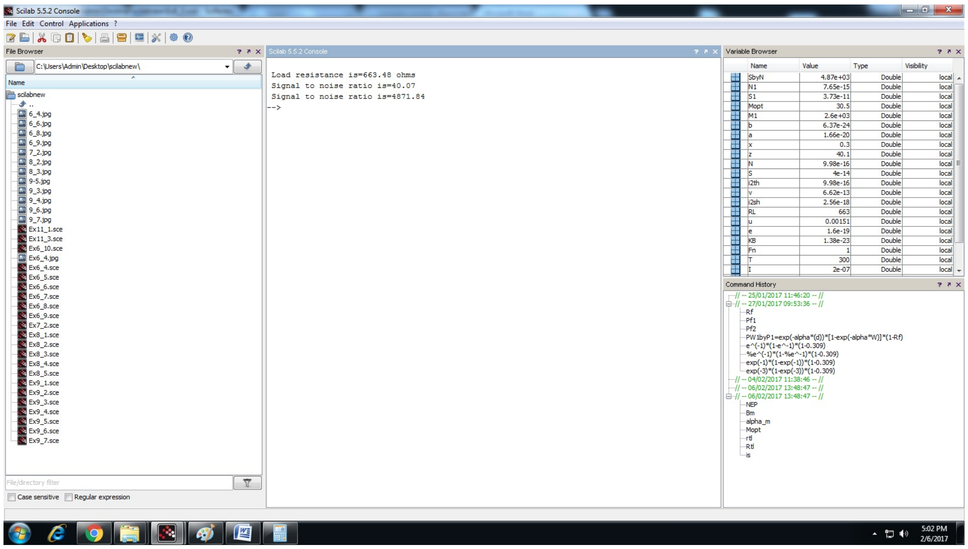

Figure 8.3: Signal to noise ratio and Multiplication factor

```

//given
Cd=5e-12;//capacitance in Farad
B=10e6;//Bandwidth in Hz

u=2*3.14*B*Cd;
RL=1/u;//Load resistance in ohms
mprintf("\n The load resistance is=%.2f *10^3ohms",RL/10^3);//multiplication factor to change unit from ohms to 10^3 ohms
v=2*3.14*RL*(10e-12);
B1=1/v;//bandwidth when the system is connected to load resistance
mprintf("\n Bandwidth when system is connected to load resistance is=%.2f MHz",B1/1e6);
//multiplcation factor to change unit to MHz from Hz
```

Scilab code Exa 8.3 Signal to noise ratio and Multiplication factor

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 8.3
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
Cd=6e-12;//capacitance in farad
Id=0;//dark current in photodiode
B=40e6;//bandwidth in Hz
I=2e-7;//photo current before gain in Ampere
T=300;//temperature in kelvin
Fn=1;
KB=1.38*1e-23//boltzman constant in SI units
e=1.6*10^-19//charge of an electron in columb
//case 1:
u=2*3.14*Cd*B;
RL=1/u;//load resistance in ohms
mprintf("\n Load resistance is=%.2f ohms",RL);

//case 2:
i2sh=2*(e)*B*I;// shot noise in A^2
v=4*(KB)*T*B;
i2th=v/RL;//thermal noise in A^2
//if i2>i1 then
S=I^2;
N=i2th;
z=S/N;
mprintf("\n Signal to noise ratio is=%.2f",z);
```

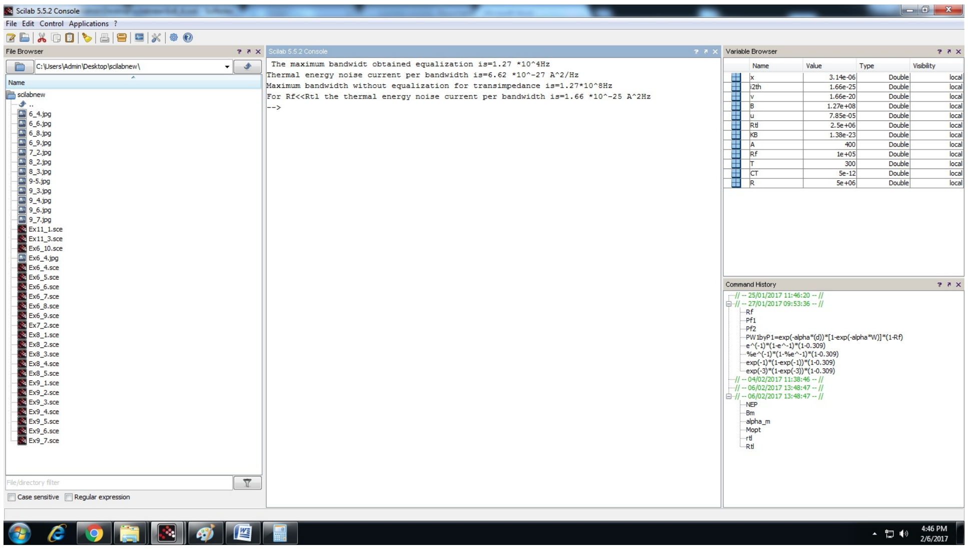

Figure 8.4: Maximum bandwidth mean square thermal noise per unit bandwidth

```
//when M=Mopt and x=0.3
x=0.3;//lies between 0.3 to 0.5 for silicon and 0.7
    to 1 for Ge
a=4*(KB)*T;
b=(e)*x*RL*I;
M1=a/b;
Mopt=M1^(1/2.3)
S1=[(Mopt)*I]^2;//signal strength in W
N1=[2*(e)*B*I*((Mopt)^2.3)]+[(4*(KB)*T*B)/(RL)];//
    noise power in W
SbyN=S1/N1;//signal to noise ratio
mprintf("\n Signal to noise ratio is=%.2f",SbyN);
//the answer in book is wrong
```

Scilab code Exa 8.4 Maximum bandwidth mean square thermal noise per unit bandwidth

```
//OptoElectronics and Fibre Optics Communication, by C.K Sarkar and B.C Sarkar
//Example 6.4
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
R=5e6;//effective resistance in ohms
CT=5e-12;//capacitance in Farads
T=300;//temperature in kelvin
Rf=1e5;//resistance in ohms
A=400;//open loop gain
KB=1.38e-23//boltzman constant in S.I. unit
//case 1:
Rtl=[(R)*(R)]/[(R)+(R)];//total effective load resistance
u=2*3.14*Rtl*CT;
B=1/u;//maximum bandwidth in Hz
mprintf("The maximum bandwidt obtained equalization is=%.2f *10^4Hz",B/1e4);//multiplication factor to change unit

//case 2:
v=4*(KB)*T;
i2th=v/Rtl;//thermal energy noise current per bandwidth in A^2/Hz
mprintf("\nThermal energy noise current per bandwidth is=%.2f *10^-27 A^2/Hz",i2th*1e27);

//case 3:
x=2*%pi*Rf*CT;
B=A/x;//maximum bandwidth without equalization for transimpedance
mprintf("\nMaximum bandwidth without equalization for transimpedance is=%.2f*10^8Hz",B/1e8);
```

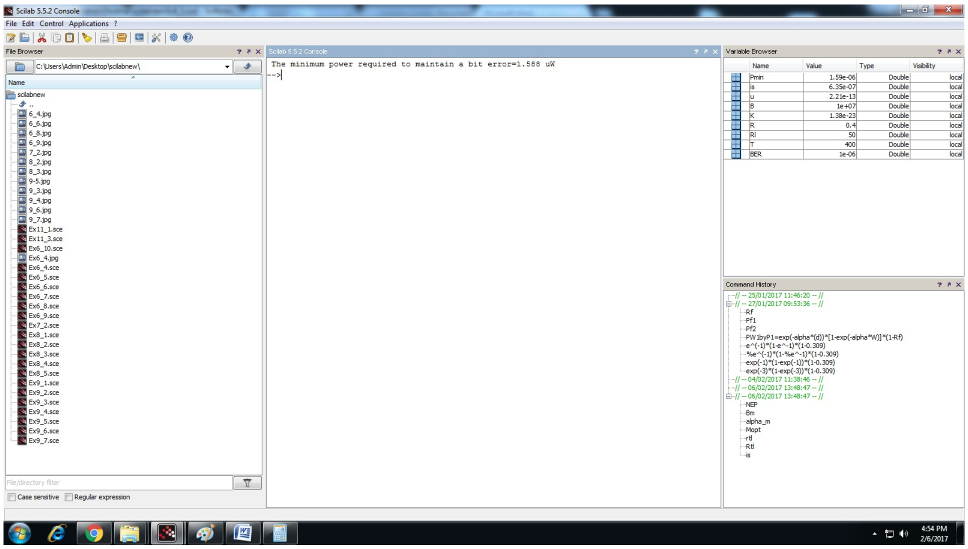

Figure 8.5: repeatno 8point4 to calculate minimum power

```
//Assuming Rf<<Rtl then the thermal energy noise
    current per bandwidth is given by
i2th=v/Rf;
mprintf("\nFor Rf<<Rtl the thermal energy noise
    current per bandwidth is=%.2f *10^-25 A^2Hz",i2th
    *1e25);
// the answer in book is wrong
```

Scilab code Exa 8.5 repeatno 8point4 to calculate minimum power

```

//OptoElectronics and Fibre Optics Communication, by
     C.K Sarkar and B.C Sarkar
//Example 6.4
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
```

```
clc;
clear;

//given
BER=1e-6;// a bit error
T=400;//temperature in kelvin
Rl=50;//load resistance in ohms
R=0.4//responsivity in A/W
K=1.38*1e-23//boltzman constant in SI units
B=1e7//bandwidth in Hz
u=4*(K)*T*B;
is=9.56*sqrt(u/Rl);//current in Ampere
Pmin=is/R;//minimum power required to maintain a bit
    error
mprintf("The minimum power required to maintain a
    bit error=%.3f uW",Pmin*1e6);
//The answer vary due to rounding
// the question no. in book is wrong there is repeat
    of 8.4
```

Chapter 9

Optical Fiber Measurements

Scilab code Exa 9.1 `Attenuation`

```

//OptoElectronics and Fibre Optics Communication, by C.K Sarkar and B.C Sarkar
//Example 91
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
L1=2;//length of fiber in m
L2=0.002;//length of fiber cutback in Km for testing
VF=2.1;//output voltage of photodetector in volts at lambda = 0.85um
lamda=0.85e-6//wavelength in m
VN=10.5;//output voltage for 2m cutback fiber length at wavelength 0.85um in volts

a=10/(L1-L2);
```

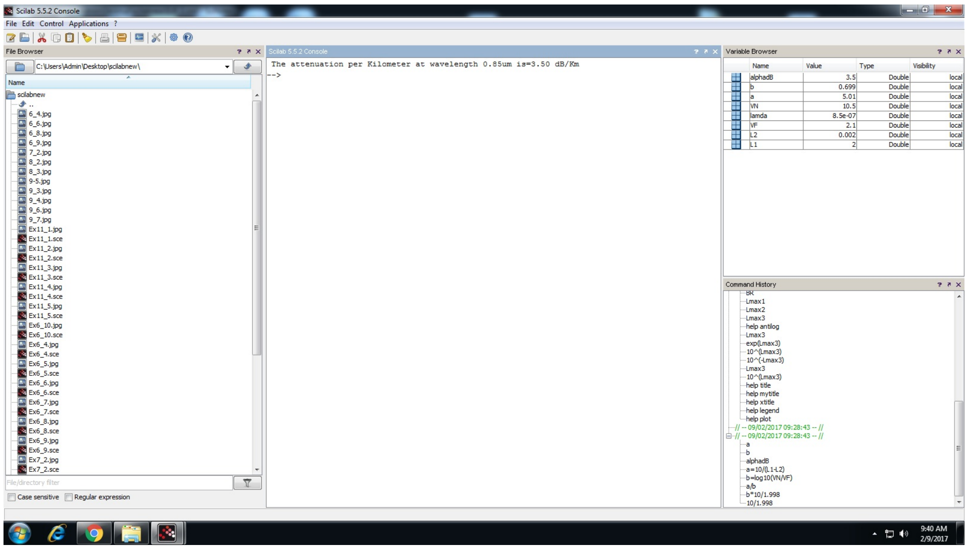

Figure 9.1: Attenuation

```
b=log10(VN/VF);
alphadB=a*b;//attenuation per Kilometer in dB/km at
    wavelength 0.85um
mprintf("The attenuation per Kilometer at wavelength
     0.85um is=%.2f dB/Km",alphadB);
```

Scilab code Exa 9.2 Attenuation

```

//OptoElectronics and Fibre Optics Communication, by
     C.K Sarkar and B.C Sarkar
//Example 9.2
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;
```

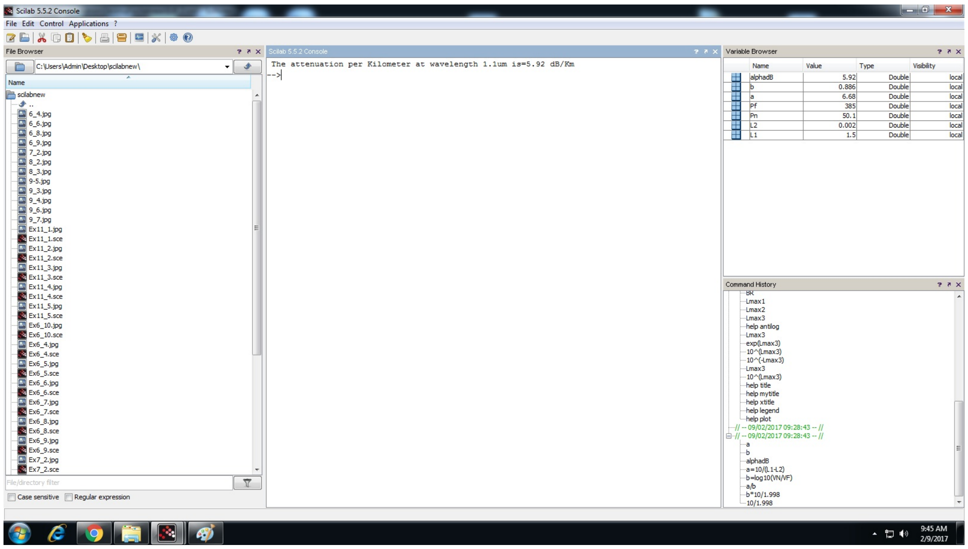

Figure 9.2: Attenuation

```

//given
L1=1.5;//length of optical fiber in Km
L2=0.002;//length of fiber cutback in Km
Pn=50.1;//output power in microwatts for the full link length
Pf=385.4;//output power in microwatts for fiber cutback

a=10/(L1-L2);
b=log10(Pf/Pn);
alphadB=a*b;//attenuation per Kilometer in dB/km at wavelength 1.1um
mprintf("The attenuation per Kilometer at wavelength 1.1um is=%.2f dB/Km",alphadB);
```

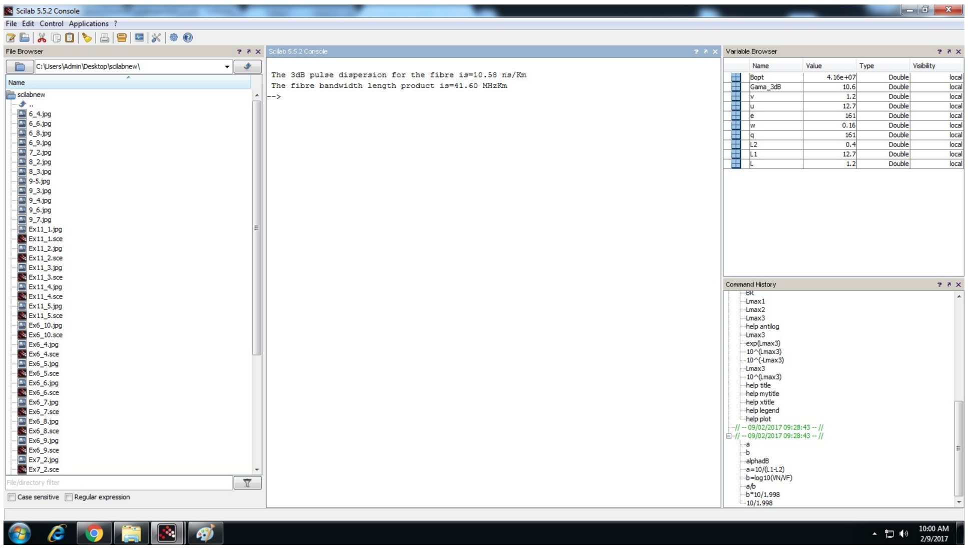

Figure 9.3: pulse dispersion and fiber bandwidth length product

Scilab code Exa 9.3 `pulse dispersion and fiber bandwidth length product`

```

//OptoElectronics and Fibre Optics Communication , by
    C.K Sarkar and B.C Sarkar
//Example 9.3
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
L=1.2//link length in Km
Gama_o=12.7;//optical output pulse of 3dB width in
    nanoseconds
Gama_i=0.4;//optical input pulse of 3dB width in
    nanosseconds

q=(Gama_o)^2;
w=(Gama_i)^2;
```

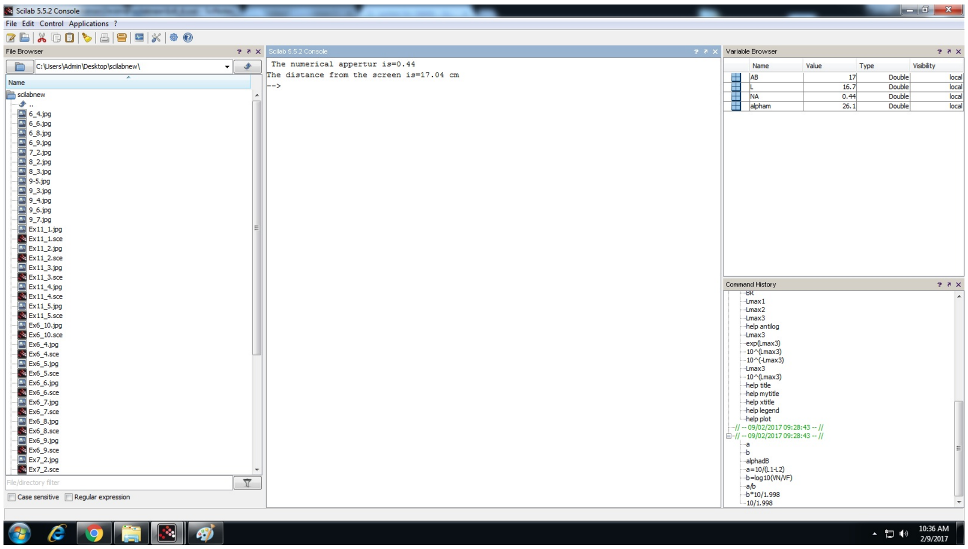

Figure 9.4: NA and distance of fiber output end face from screen

```
e=q-w;
u=sqrt(e);
v=1.2;
Gama_3dB=u/v;//3dB pulse dispersion for the fibre in
    ns/Km
mprintf("\n The 3dB pulse dispersion for the fibre
   is=%.2f ns/Km",Gama_3dB);
Bopt=0.44/(Gama_3dB*1e-9);//fibre bandwidth length
   productmultiplication by 1e-9 as gama is in nsKm
mprintf("\n The fibre bandwidth length product is=%
   .2f MHzKm",Bopt/1e6); //multiplication by 1e6 to
   convert unit from Hz to MHz
//the answer vary due to rounding
```

Scilab code Exa 9.4 NA and distance of fiber output end face from screen

```
//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 9.4
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
alpham=26.1;//angular limit of far field pattern in
   degrees
NA=sind(alpham);//numerical aperture
L=16.7;//length of picture in cm

AB=(L/2)/[tand(alpham)];//distance from the screen
   in cm
mprintf("The numerical appertur is=%.2f ",NA);
mprintf("\nThe distance from the screen is=%.2f cm",
   AB);
//th answer vary due to rounding
```

Scilab code Exa 9.5 NA

```
//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 9.5
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

```

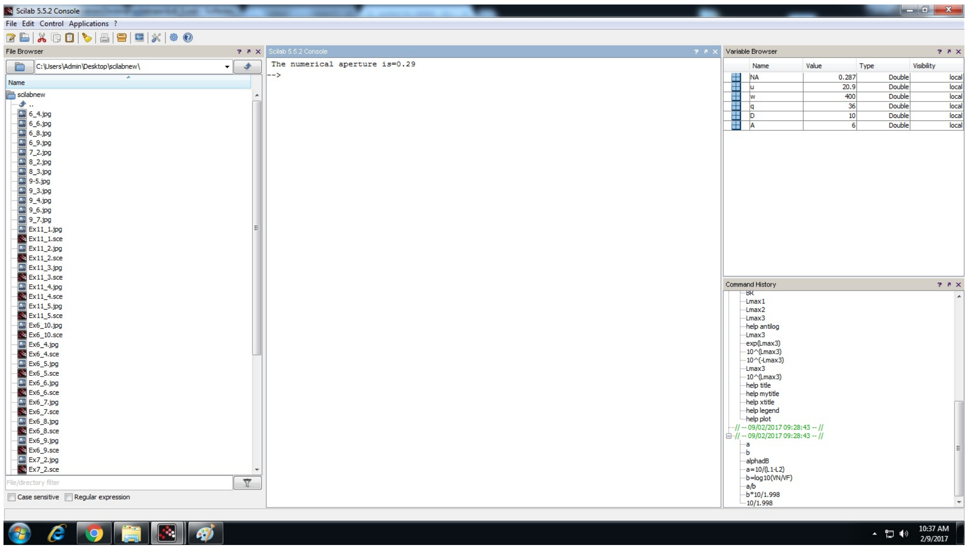

Figure 9.5: NA

```
//given
A=6.0;//measured output pattern size in cm
D=10.0;//distance between the screen and fibre face in cm

q=(A)^2;
w=4*D^2;
u=sqrt(q+w);
NA=A/u;//numerical aperture
mprintf("The numerical aperture is=%.2f",NA);
```

Scilab code Exa 9.6 repeatno9point4 determine outer diameter of fiber

```

//OptoElectronics and Fibre Optics Communication, by C.K Sarkar and B.C Sarkar
```

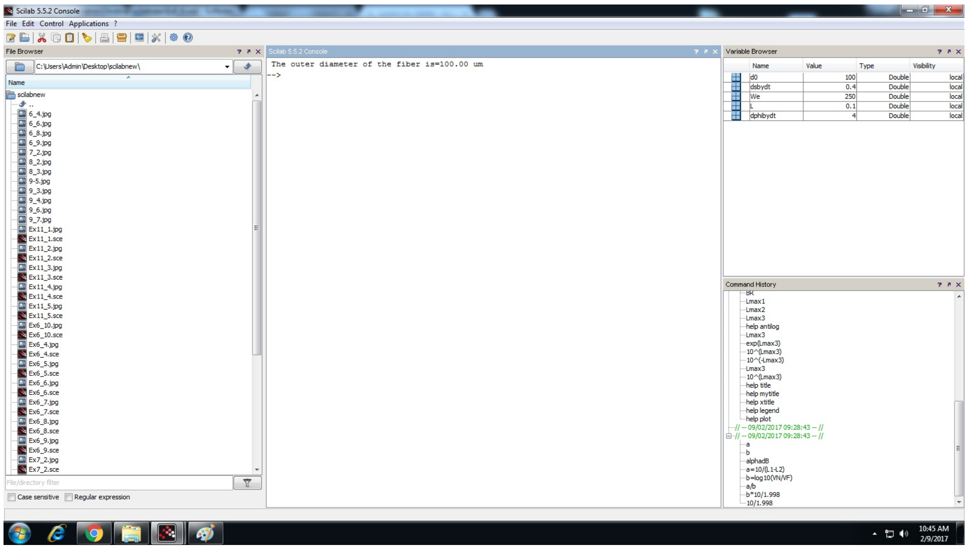

Figure 9.6: repeatno9point4 determine outer diameter of fiber

```
//Example 9.6
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
dphibydt=4;//angula velocity of roatng mirror in rad
    /sec
L=0.1;//distance between mirror and the detector in
    meter
We=250;//shadow pulse width in micrometer;

dsbydt=L*dphibydt;
d0=We*[dsbydt];//outer diameter of the fiber in
    micrometer
mprintf("The outer diameter of the fiber is=%.2f um"
    ,d0);
```

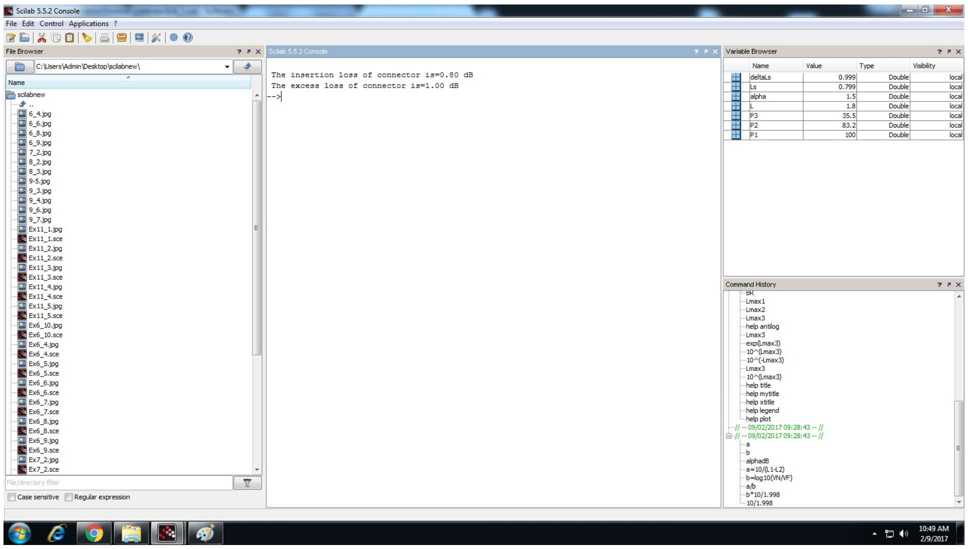

Figure 9.7: repeatno9point5 calculate excess loss of the connector

Scilab code Exa 9.7 `repeatno9point5 calculate excess loss of the connector`

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 9.7
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
P1=100;//power at the input in microwatts
P2=83.2;//power at the output in microwatts
P3=35.5;//power at the ouput after connector in
```

```
microwatts
L=1.8;//length of the added fibre in Km
alpha=1.5;//fiber attenuation in dB/L;

//case 1:
Ls=-10*log10(P2/P1);//insertion loss of connector in dB
mprintf("\n The insertion loss of connector is=%.2f dB",Ls);

//case 2:
deltaLs=-10*log10(P3/P1)-Ls-alpha*L;//excess loss of the connector
mprintf("\n The excess loss of connector is=%.2f dB",deltaLs);
```

Chapter 11

Optical Fiber Links and Wavelength Division Multiplexers

Scilab code Exa 11.1 material dispersion delay

```

//OptoElectronics and Fibre Optics Communication, by C.K Sarkar and B.C Sarkar
//Example 11.1
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
L=1.25e3;//length of the link in m
delta_lamda=45;//change in wavelength in nanometers
lamda=850;//perating wavelength of fibre in nanometer
C=3e8;//velocity of light in m/s
```

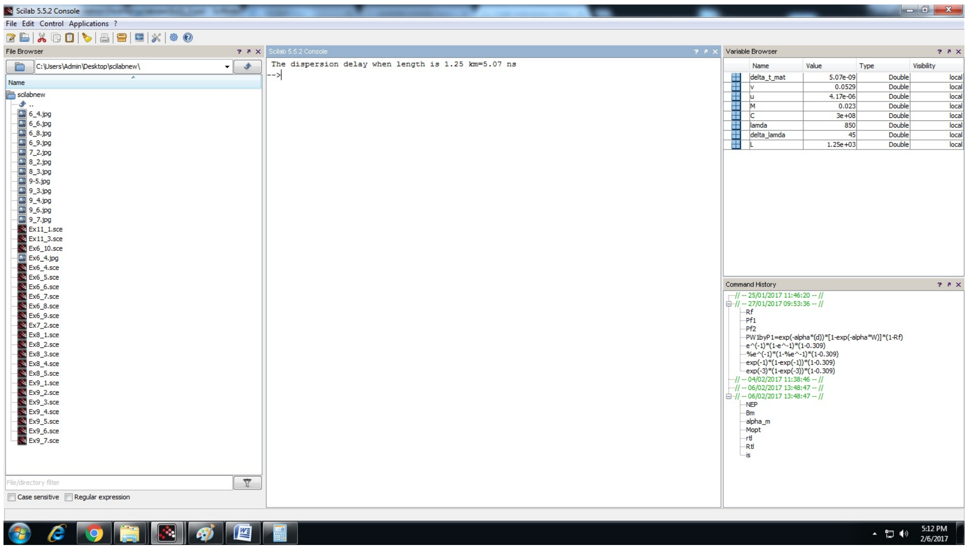

Figure 11.1: material dispersion delay

```
M=0.023;//value of material dispersion parameter

u=L/C;
v=delta_lamda/lamda;
delta_t_mat=u*v*0.023;//dispersion delay when length
    is 1.25 km
mprintf("The dispersion delay when length is 1.25 km
   =%.2f ns",delta_t_mat*1e9);
```

Scilab code Exa 11.2 material dispersion limited transmission distance

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 11.1
//OS=Windows 10
```

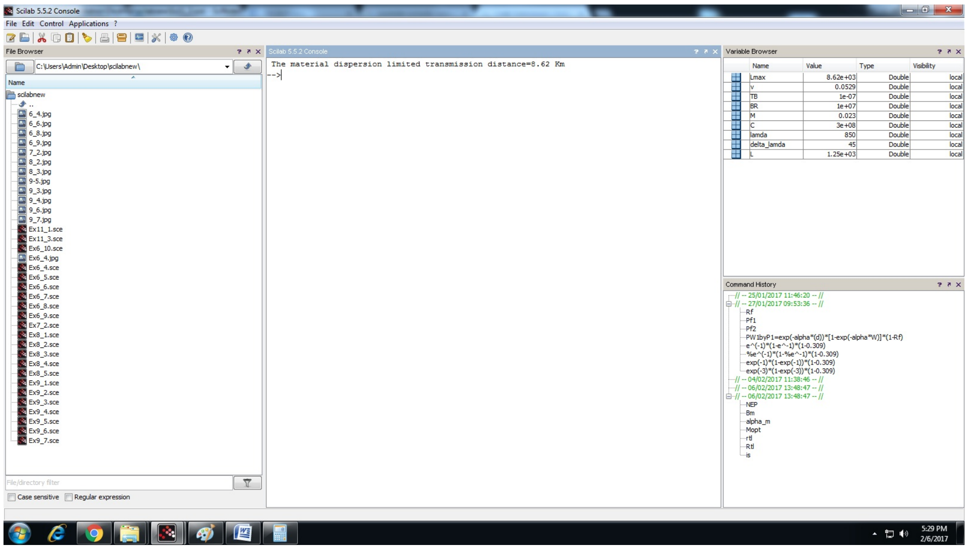

Figure 11.2: material dispersion limited transmission distance

```
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
L=1.25e3;//length of the link in m
delta_lamda=45;//change in wavelength in nanometers
lamda=850;//perating wavelength of fibre in nanometer
C=3e8;//velocity of light in m/s
M=0.023;//value of material dispersion parameter
BR=1e7//bitate in bps
TB=1/BR//bit period in s
v=delta_lamda/lamda;
Lmax=0.35*TB*C/(M*v)//The material dispersion limited transmission distance

mprintf("The material dispersion limited transmission distance=%.2f Km",Lmax/1e3);
```

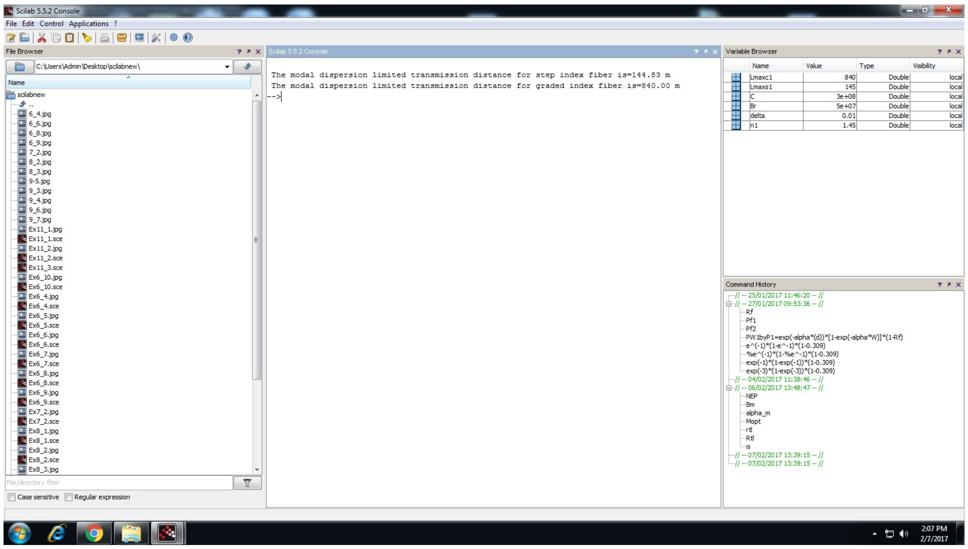

Figure 11.3: modal dispersion limited transmission distance

Scilab code Exa 11.3 modal dispersion limited transmission distance

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 11.3
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
n1=1.45//refractive index of core
delta=0.01;//relative refractive index difference
Br=50e6;//data rate in bps
```

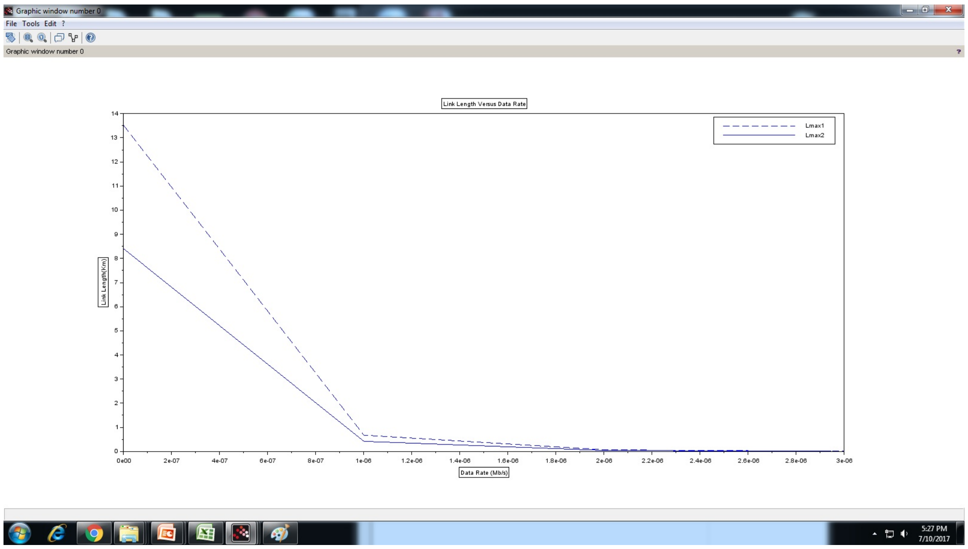

Figure 11.4: material dispersion modal and attenuation limited distance and length versus data rate

```
C=3e8// velocity of light in m/s
//for step index fibre
Lmaxs1=0.35*C/(delta*n1*Br);//modal dispersion limited transmission distance in meter for step index fiber
mprintf("\n The modal dispersion limited transmission distance for step index fiber is=%.2f m",Lmaxs1);
//for graded index fibre

Lmaxc1=1.4*C*n1/(delta*n1*Br);;//modal dispersion limited transmission distance in meter for graded index fiber
mprintf("\n The modal dispersion limited transmission distance for graded index fiber is=%.2f m",Lmaxc1);
```

Scilab code Exa 11.4 material dispersion modal and attenuation limited distance an

```
//OptoElectronics and Fibre Optics Communication, by C.K Sarkar and B.C Sarkar
//Example 11.4
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given

BR=[0.5e6 10e6 100e6 1000e6]//data rate in bps

for i=1:4
Lmax1(i)=6.757e10/BR(i)//Material dispersion limited distance in m
Lmax2(i)=4.2e10./BR(i)//modal limited distance in m
Lmax3(i)=(55-20*log10(BR(i)))//attenuation limited distance in m
end
BR=[0 1 2 3]
plot((BR)/1e6,Lmax1/1e4,'--')
plot((BR)/1e6,Lmax2/1e4)
//plot(log10(BR),(10^(Lmax3)/1e6)'-.-.')
xtitle( 'Link Length Versus Data Rate', 'Data Rate (Mb/s)', 'Link Length(Km)', boxed = %t );
hl=legend(['Lmax1';'Lmax2']);
```

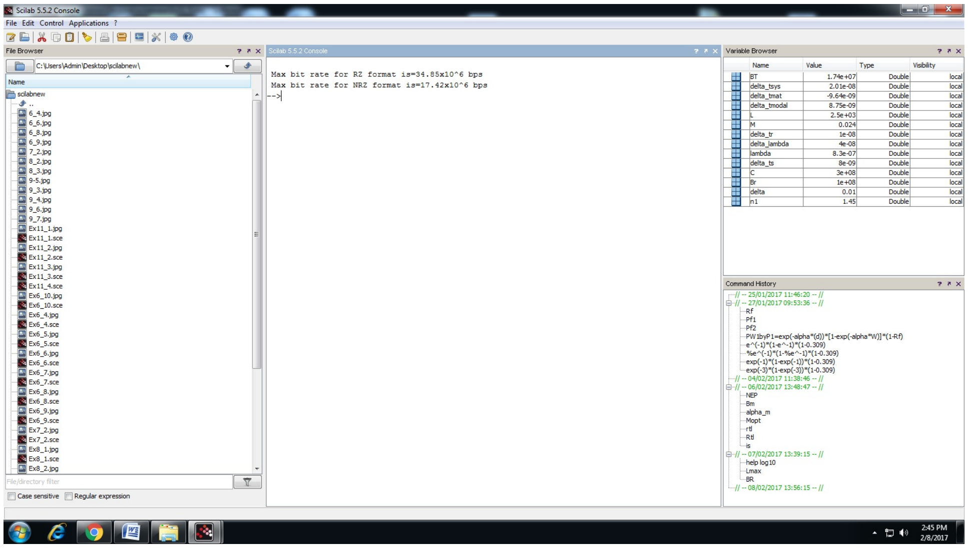

Figure 11.5: maximum bit rate

Scilab code Exa 11.5 `maximum bit rate`

```

//OptoElectronics and Fibre Optics Communication, by
    C.K Sarkar and B.C Sarkar
//Example 11.5
//OS=Windows 10
////Scilab version Scilab 6.0.0-beta-2(64 bit)
clc;
clear;

//given
n1=1.45//refractive index of core
delta=0.01;//relative refractive index difference
Br=100e6;//data rate in bps
C=3e8// velocity of light in m/s
delta_ts=8e-9//silica fiber link rise time in s
lambda=830e-9//wavelength in m
delta_lambda=40e-9//spectral width in m
delta_tr=10e-9//rise time in 10ns
```

```
M=0.024//silica fiber parameter
L=2.5e3//length of link in m
delta_tmodal=3.5e-9*L/1e3//intermodal dispersion
    delay in s
delta_tmat=(-L/C)*(delta_lambda/lambda)*(M)//
    material dispersion in s
delta_tsys=1.1*sqrt(delta_ts^2+delta_tr^2+delta_tmat
    ^2+delta_tmodal^2)//system delay in s
BT=0.7/delta_tsys//Max bit rate for RZformat
mprintf("\n Max bit rate for RZ format is=%.2fx10^6
    bps",BT/1e6);//division by1e6 to convert the unit
     from bps to *10^6
BT=0.35/delta_tsys//Max bit rate for NRZformat
mprintf("\n Max bit rate for NRZ format is=%.2fx10^6
     bps",BT/1e6);
// the answer differ because of roundoff
```