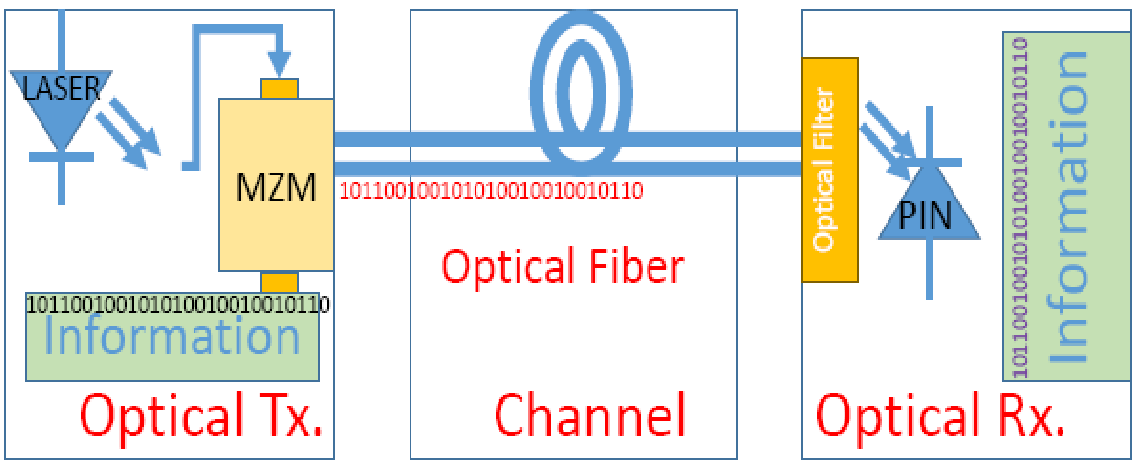
EXP NO: 13 SIMULATION OF OPTICAL COMMUNICATION SYSTEM (USING OPTILUX)

13.1 OBJECTIVE

To simulate and study the performance of Optical communication system using an open source OptiLux Toolbox (for Matlab and Octave)

The Link for OptiLux : "http://optilux.sourceforge.net"

13.2 SCHEMATIC BLOCK DIAGRAM



13.3 PRELAB QUESTIONS

1. What are the major components of an optical communication system?
2. Define minimum detectable optical power.
3. What is meant by error rate?
4. What are the error sources of optical receiver?

13.4 OPTILUX

Optilux is an open source collection of tools that provide advanced techniques to design, simulate, and analyze optical communication systems. Optilux is implemented as a Matlab/Octave toolbox and efficiently exploits the MEX inter face to speed up computation. Optilux was created by Prof. Paolo Serena and it was primarily intended as a replacement for the old Fortran code he used for his simulations. Optilux is released under the GNU General Public License, version 3.

Optilux is a collection of .m files, each representing a specific block of an optical system. The top-to-bottom flow on a .m file corresponds to moving over the distance of the optical system. Each block of an optical system is realized using Optilux toolbox functions. All the toolbox functions are M-files that implement specialized Optilux algorithms.

13.4.1 OPTILUX TOOLBOX FUNCTIONS

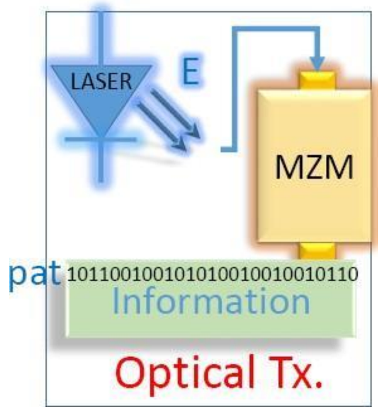
RESET_ALL(NSYMB,NT,NCH)	AMPLIFLAT(X,ATYPE)	E=AVG_POWER(ICH,FLAG)
CREATE_FIELD(FTYPE,SIGX)	OPTFILTER(ICH,FTYPE,BW)	HF=MYFILTER(FTYPE,F,BW)
PB=BER_KL(ICH,X,PAT)	[EO, TS]=EVAL_EYE(ICH,X,PAT)	Y=EVALDELAY(FTYPE,BW)
PAT=PAT_DECODER(PAT,MODFORMA T)	PAT=PATTERN(PTYPE,NSEED,OPTIONS)	DELAY=CORRDELAY(IRIC,PAT,N T, NSYMB)
ELEC=ELECTRICSOURCE(PAT, FORMAT, SYMBRATE, PTYPE, DUTY, ROLL)	PHI=POW2PHI(PWR,L,ALPHA,GAM,G,NS PAN)	EOUT=LPFILTER(EIN,FTYPE,B W,OR D)
E=LASERSOURCE(PTX,LAM)	[BSP,BPOST]=BEST_SP(ICH,X,PAT)	POLARIZER(ANG1,ANG2,ANGTYP E)
E=LINEAR_MODULATOR(E,MODSIG,E XRA TIO)	[COND,OUT]=MC_ESTIMATE(S,X)	PLOTFIELD(POL,ICH,FLAG)
E=MZ_MODULATOR(E,MODSIG)	POLAR(PHASES,AMPLITUDES)	PLOTFILE(FILE)
E=PHASE_MODULATOR(E,MODSIG)	Y=FASTSHIFT(X,N)	PRINTFIELD(POL,ICH,NAME,FLAG)
FIBER(X,FLAG)	[BEYE,BPOST]=BEST_EYE(ICH,X,PAT)	Q=BER2Q(BER)

13.4.2 STEPS TO BE FOLLOWED FOR SIMULATION

- Open MATLAB simulator window and create a new document.
- Click Save As, give the file name as ‘**Optical_exp1**’and save it in ‘**…/Optilux_v0.1/Optilux_files**’ folder.
- On completion of the code, after clicking the ‘**Run**’ button, click on the ‘**Change Folder**’ button.

13.5 PROGRAM

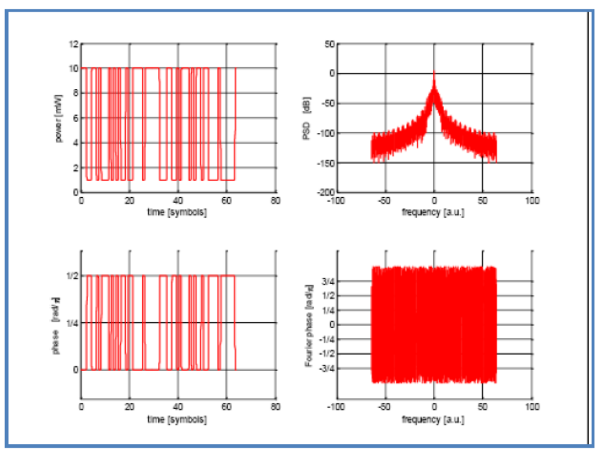
13.5.1 FOR OPTICAL TRANSMITTER



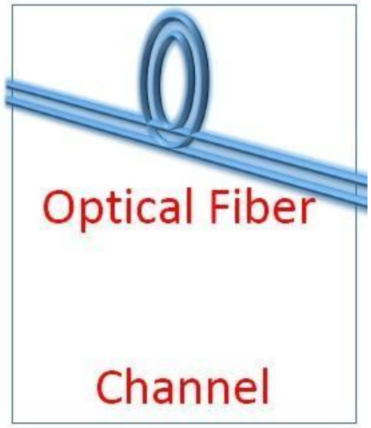

```
clear all
 clc
 %%%%%%%%%%%%%%%%%% Field parameters
 Nsymb = 64;      % number of symbols
 Nt    = 128;     % points x symbol
 Nch   = 1;       % number of channels

reset_all(Nsymb,Nt,Nch);

%%
 Ppeak = 10;  %Power Peak *(1:Nch);
 lam   = 1550;% central wavelength [nm]
 spac  = 0.8; % channel spacing [nm]

E=lasersource(Ppeak, lam, spac);
%%
```

```
 pat=pattern('debruijn',4);    % note the
different de Bruijn seeds
%%
 symbrate = 10;       % baudrate [Gbaud](10Gb/s)
 duty     = 1;        % duty cycle
 roll     = 0.2;      % pulse roll-off


elec=electricsource(pat,'ook',symbrate,'co
sroll',duty,roll);
%%
    exratio     = 10;    % extinction ratio [dB]


Eopt=mz_modulator(E,elec,struct('exratio',
exratio));
```

```
create_field('unique',Eopt);

     figure(1)
    plotfield('x',1,'p---','r-');

    figure(2)
    plotfield('x',1,'--p-','r-');

    figure(3)
    plotfield('x',1,'-a--','r-');

    figure(4)
    plotfield('x',1,'---a','r-');

    figure(5)
    plotfield('x',1,'papa','r-');
```

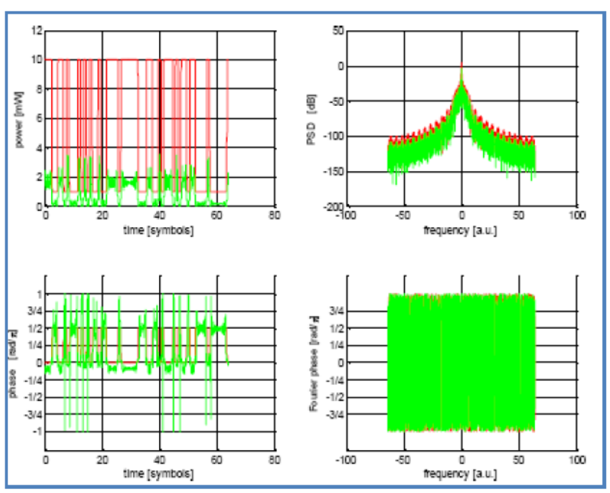


13.5.2 PROGRAM TO DESIGN OPTICAL CHANNEL (OPTICAL FIBER)

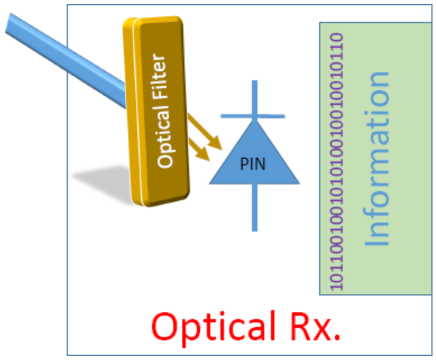



```
%%
 %%%%%%%%%%%%%%%% Link parameters
%%%%  Fiber 1 (Tx)  Corning® LEAF®
Optical %Fiber  Product Information

tx.length  = 4e4;      % length [m]
tx.alphadB = 0.2;      % attenuation [dB/km]
tx.aeff    = 72;       % effective area [um^2]
tx.n2      = 2.7e-20;  % nonlinear index
tx.lambda  = 1550;  % λ [nm] @ dispersion
tx.disp    = 16.75; % dispersion[ps/nm/km]@λ
tx.slope   = 0.075; % slope [ps/nm^2/km]@λ
tx.dphimax = 3E-3;  % maximum nonlinear phase
                      rotation per step
tx.dzmax   = 2E4;   % maximum SSFM step

  %%%%%%%%%% Optical link
fiber(tx,'g-sx'); % Tx fiber
%%
```

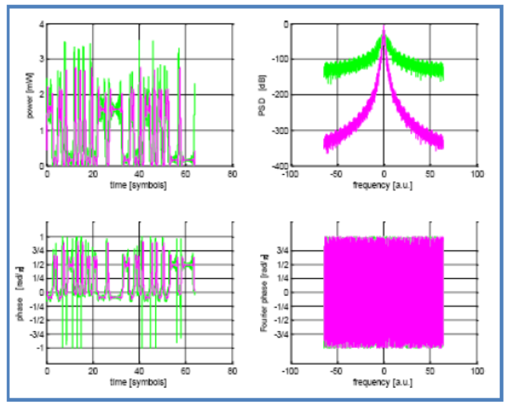
```
      figure(1)
      plotfield('x',1,'p---','g-');
      figure(2)
      plotfield('x',1,'--p-','g-');
      figure(3)
      plotfield('x',1,'-a--','g-');
      figure(4)
      plotfield('x',1,'---a','g-');
      figure(5)
      plotfield('x',1,'papa','g-');
%%
```



13.5.3 PROGRAM FOR OPTICAL FILTER & RECEIVER




```
%%%%%%%%%%%%%%%%% Receiver parameters

oftype = 'butt6'; % optical filter type
obw    = 2.5;     % optical filter bandwidth

optfilter(1,oftype,obw);
%%
    figure(6)
    plotfield('x',1,'p---','m-');
    figure(7)
    plotfield('x',1,'--p-','m-');
    figure(8)
    plotfield('x',1,'-a--','m-');
    figure(9)
    plotfield('x',1,'---a','m-');
    figure(10)
    plotfield('x',1,'papa','m-');
```

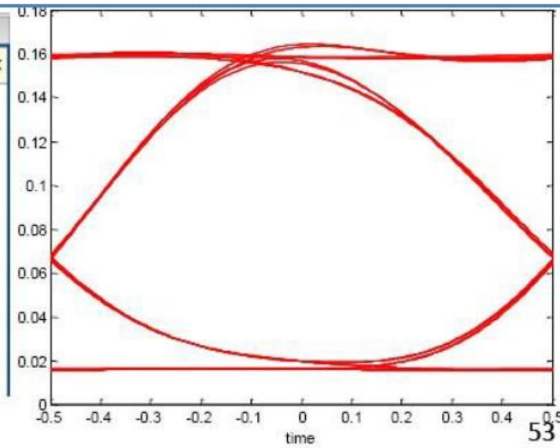


Optical Receiver

```
%%

x.oftype = 'gauss';    % optical filter type
x.obw    = 2.5;        % optical filter bandwidth
x.eftype = 'bessel5';  % electrical filter type
x.ebw    = 0.65;       % electrical filter BW
x.rec    = 'ook';      % receiver type
x.plot   = 'ploteye';  % type of plot
x.color  = 'r-';       % color of plot
x.slopez =0;     %post-fiber cumulated slope [ps/nm^2]
x.lambda = lam; % post-fiber central wavelength [nm]
x.dpost  = -670; % post-fiber cumulated dispersion [ps/nm]
```

```
figure(11)
pat_rx = pat_decoder(pat,'ook'); % pattern decoding

[eo,ts]=eval_eye(Nch,x,pat_rx);

fprintf('\n\n====== Results ======\n\n');
fprintf('Normalized Eye opening = %.4f\n',eo);
fprintf('Best sampling time = %f\n',ts);
fprintf('Post fiber dispersion =%.2f [ps/nm]\n',x.dpost);
```

```
Command Window          Editor - Program_1.m
New to MATLAB? Watch this Video, see Examples, or read Getting Started.

=========== Results ===========

Normalized Eye opening = 0.1334
Best sampling time = -0.073776
Post fiber dispersion =-670.00 [ps/nm]
Warning: Plot or print turned off during the search of the
optimal post
> In best_eye at 124
  In Program_1 at 136
```



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Repeat the experiment by varying the following and observe the results

1. Change symbrate and observe the change
2. Change roll and observe the change
3. Increase exratio and see the change in EYE
4. Increase tx.length and observe the change
5. Change oftype and observe the change
6. Change obw and observe the change
7. Change x.oftype and see the change in EYE
8. Change x.obw and see the change in EYE
9. Change x.ebw and see the change in EYE

```matlab
clear all
 clc

 %%%%%%%%%%%%%%%% Field parameters
 Nsymb = 64;      % number of symbols
 Nt    = 128;     % points x symbol
 Nch   = 1;       % number of channels

 reset_all(Nsymb,Nt,Nch);
%%
 Ppeak = 10;        %Power Peak *(1:Nch);[mW]
 lam      = 1550;    % central wavelength [nm]
 spac     = 0.8;     % channel spacing [nm]

  E    = lasersource(Ppeak, lam, spac);
%%
 pat=pattern('debruijn',4);     % note the different de Bruijn seeds
%%
 symbrate = 10;      % baudrate [Gbaud](10Gb/s)
 duty     = 1;       % duty cycle
 roll     = 0.2;     % pulse roll-off

  elec=electricsource(pat,'ook',symbrate,'cosroll',duty,roll);
%%
 exratio    = 10;   % extinction ratio [dB]

    Eopt=mz_modulator(E,elec,struct('exratio',exratio));
%%
create_field('unique',Eopt);
     figure(1)
     plotfield('x',1,'p---','r-');
     figure(2)
     plotfield('x',1,'--p-','r-');
     figure(3)
     plotfield('x',1,'-a--','r-');
     figure(4)
     plotfield('x',1,'---a','r-');
     figure(5)
     plotfield('x',1,'papa','r-');
%%
```

```
                    %%%%%%%%%%%%%%%% Link parameters
 %%%% Fiber 1 (Tx) Corning® LEAF® Optical Fiber Product Information

tx.length = 4e4;       %
length [m] tx.alphadB = 0.2;
                       %
attenuation [dB/km]
tx.aeff    = 72;       %
effective area [um^2] tx.n2 =
2.7e-20; % nonlinear index
tx.lambda = 1550;      % wavelength [nm] @ dispersion
tx.disp    = 16.75;       % dispersion [ps/nm/km] @
wavelength tx.slope   = 0.075;    % slope
[ps/nm^2/km] @ wavelength tx.dphimax = 3E-3;  %
maximum nonlinear phase rotation per step tx.dzmax
           = 2E4;     % maximum SSFM step

%%%%%%%%%% Optical link
fiber(tx,'g-sx');        % Tx fiber
%%___ figure(1)
     plotfield('x',1,'
     p---','g-');
     figure(2)
     plotfield('x',1,'
     --p-','g-');
     figure(3)
     plotfield('x',1,'
     -a--','g-');
     figure(4)
     plotfield('x',
     1,'---a','g-
     '); figure(5)
     plotfield('x',
     1,'papa','g-
     ');

     figure(6)
     plotfield('x',1,'
     p---','g-');
     figure(7)
     plotfield('x',1,'
     --p-','g-');
     figure(8)
     plotfield('x',1,'
     -a--','g-');
     figure(9)
     plotfield('x',
     1,'---a','g-
     '); figure(10)
     plotfield('x',
     1,'papa','g-
     ');
%%________________________________________________________________________________
%%%%%%%%%%%%%%%%
Receiver parameters of
type = 'butt6'; %
optical filter type
```

```
obw    = 2.5;     % optical filter bandwidth

optfilter(1,oftype,obw);
%%___ figure(6)
     plotfield('x',1,'
     p---','m-');
     figure(7)
     plotfield('x',1,'
     --p-','m-');
     figure(8)
     plotfield('x',1,'
     -a--','m-');
     figure(9)
     plotfield('x',
     1,'---a','m-
     '); figure(10)
     plotfield('x',
     1,'papa','m-
     ');
%%________________________________________________________________________________


x.oftype = 'gauss';   % optical
filter type x.obw     = 2.5;
         % optical filter
bandwidth x.eftype = 'bessel5'; %
electrical filter type
x.ebw    = 0.75;      % electrical
filter bandwidth x.rec      = 'ook';
         % receiver type
x.plot   = 'ploteye';
% type of plot x.color
= 'r-';  % color of
plot
x.slopez = 0;         % post-fiber cumulated
slope [ps/nm^2] x.lambda = lam;   % post-fiber
central wavelength [nm] x.dpost = -670; % post-
fiber cumulated dispersion [ps/nm]

figure(11)
pat_rx = pat_decoder(pat,'ook'); %
pattern decoding
[eo,ts]=eval_eye(Nch,x,pat_rx);

fprintf('\n\n=========== Results
===========\n\n');
fprintf('Normalized Eye opening =
%.4f\n',eo); fprintf('Best sampling
time = %f\n',ts);
fprintf('Post fiber dispersion =%.2f [ps/nm]\n',x.dpost);
%%________________________________________________________________________________

%%%%%% now search for the optimal
post compensation dpostini =
x.dpost;
x.dpost = [-1500 1500]; % range for the search
```

```
[be,bpost] = best_eye(Nch,x,pat_rx);
% During the search of the best post you will see the following
warning:
% Warning: Plot or print turned off during the search of the optimal
post.

fprintf('\nBest Eye closure penalty = %.4f
[dB]\n',be); fprintf('Best post cumulated dispersion
= %.2f [ps/nm]\n\n',bpost); fprintf('\nOther details
into the summary file simul_out\n');

figure(11)    % Re-plot the best eye, just
for comparison hold on
title(['RED: post = ',num2str(dpostini),' ps/nm, BLUE: best post =
    ',... num2str(bpost),' ps/nm']);

x.dpost = bpost; % use
the best post x.color
= 'b-';            %
change color
[eo2,ts2]=eval_eye(Nch
,x,pat_rx);

% The blue eye is better than the red one... it is the best eye!
%%
```

13.6 POST LAB QUESTIONS

1. How is an electrical signal converted into an optical signal
2. Why do we need modulation in optical communication?
3. What is the significance of an eye diagram in optical communication system?

13.7 RESULT

Thus the Optical communication system is simulated and its performance is studied