



SC454 Silicon Photonics Circuits and Systems Design

OFC SHORT COURSE MARCH – 20TH, 2017



INTERCONNECT

Photonic Integrated Circuit Simulator

INTERCONNECT GUI

Results Properties Schematic Visualizers Library Script editor

Run

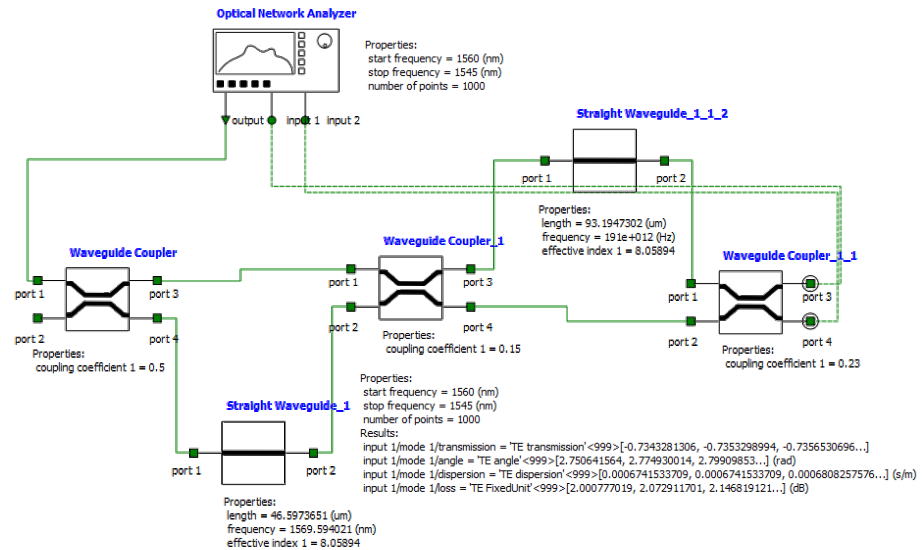
The screenshot displays the Lumerical INTERCONNECT GUI with several panels and components labeled with red arrows:

- Results:** A table showing simulation results for an optical network analyzer (ONA).
- Properties:** A table showing the properties of the ONA, including its name, type, and model.
- Schematic:** A diagram showing the optical network topology, including waveguides (WC1, WC2, WC3), switches (SW1, SW2), and an optical network analyzer (ONA).
- Visualizers:** A plot showing the TE gain (dB) versus frequency (THz).
- Library:** A list of components available in the library, including sources, modulators, passives, and waveguides.
- Script editor:** A text editor showing the script used to generate and run the analysis.
- Element tree:** A tree view showing the hierarchy of the simulation components.
- Ports:** A table showing the ports of the simulation components.
- Script prompt:** A text area for entering commands to run the simulation.
- Output:** A text area showing the output of the simulation.
- Optimizations and sweeps:** A panel for configuring optimization and sweep parameters.

Element tree Ports Script prompt Output Optimizations and sweeps

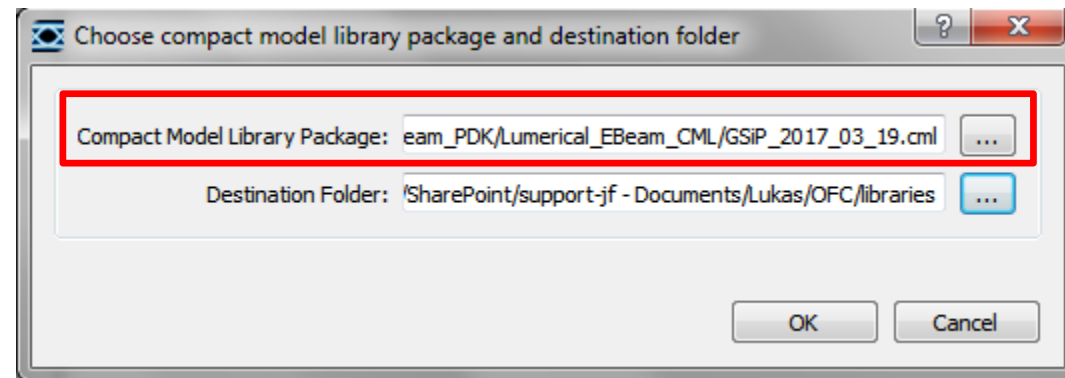
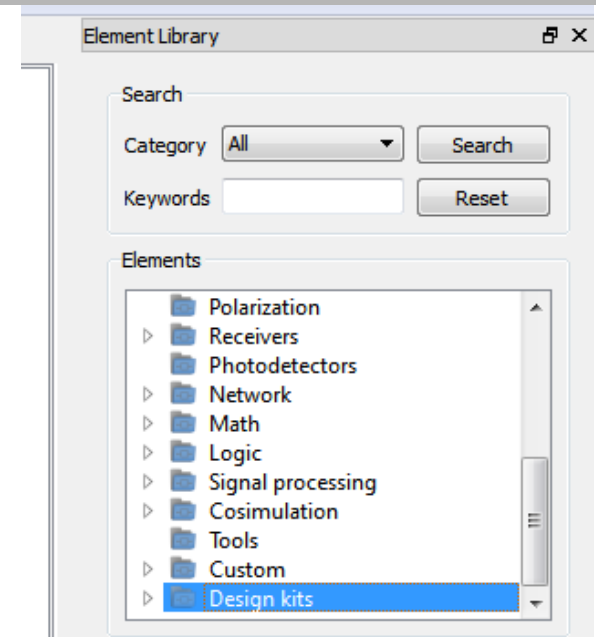
INTERCONNECT workflow

- Add circuit elements
- Add connections
- Add analyzer elements
- Set properties
- Run simulation
- Visualize results



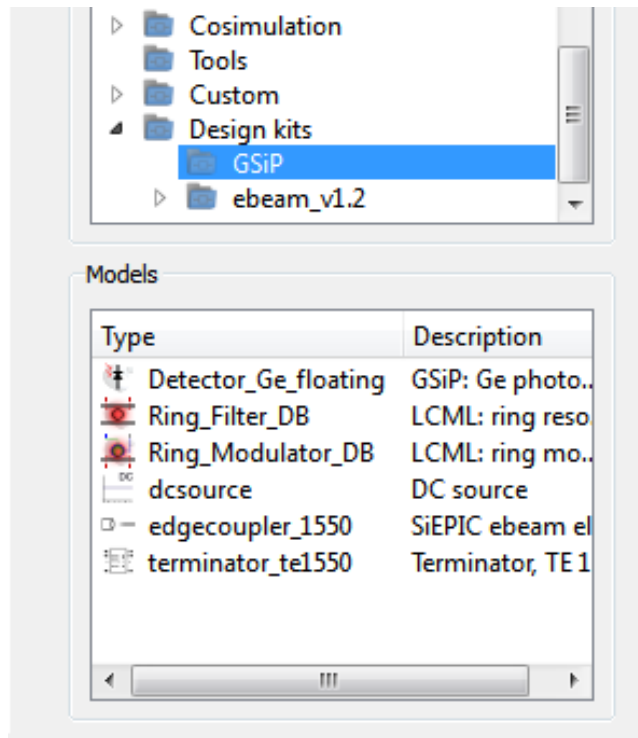
Install a compact model library

- Left mouse click on 'Design Kit' at the bottom of the element library
- Browse for the latest GSiP *.cml file (in the folder SiEPIC_Ebeam_PDK/Lumerical_Ebeam_CML)
- Choose a destination folder
- Repeat with the latest EBeam compact model library

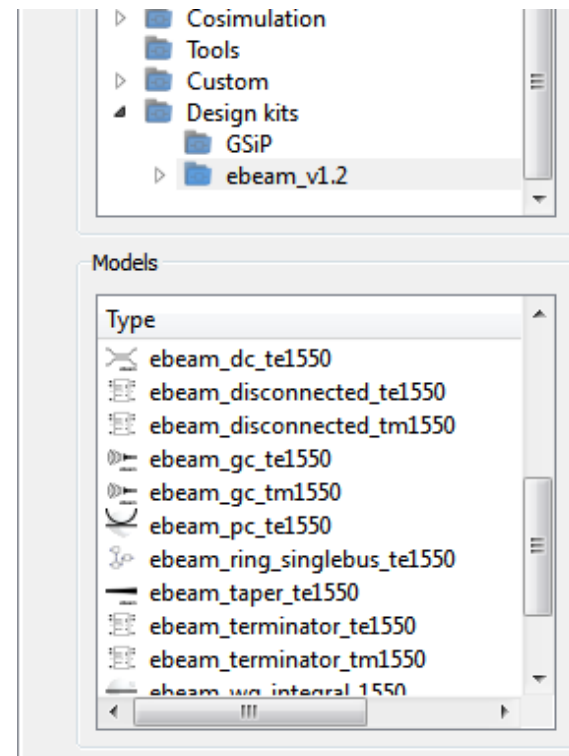


Compact model libraries

GSiP CML (active)

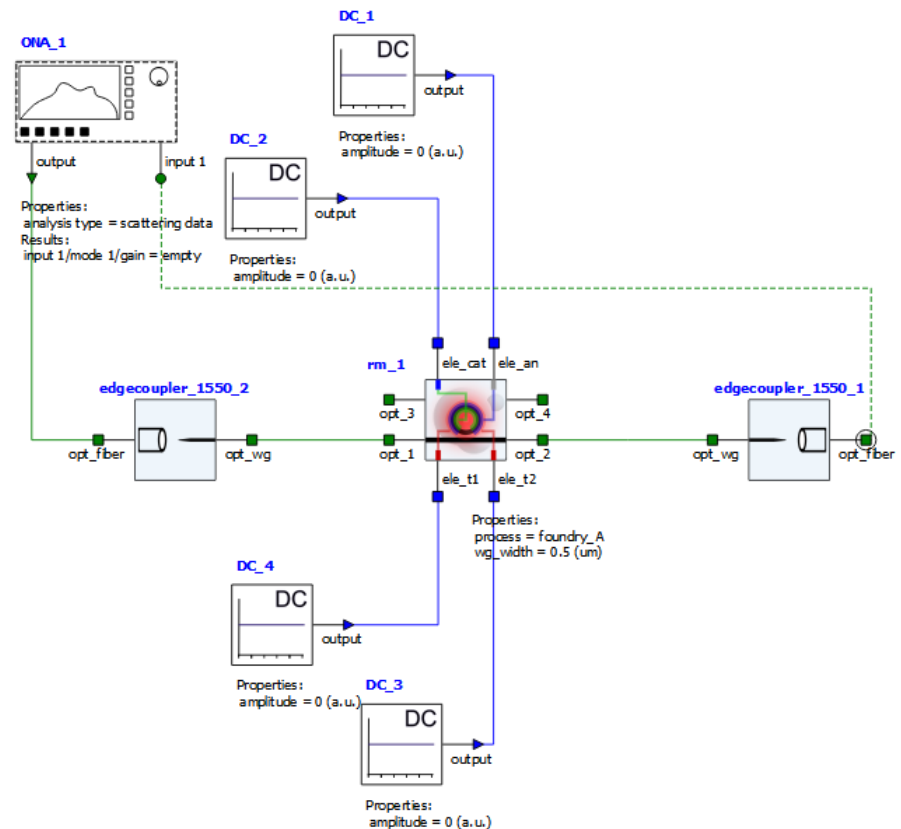
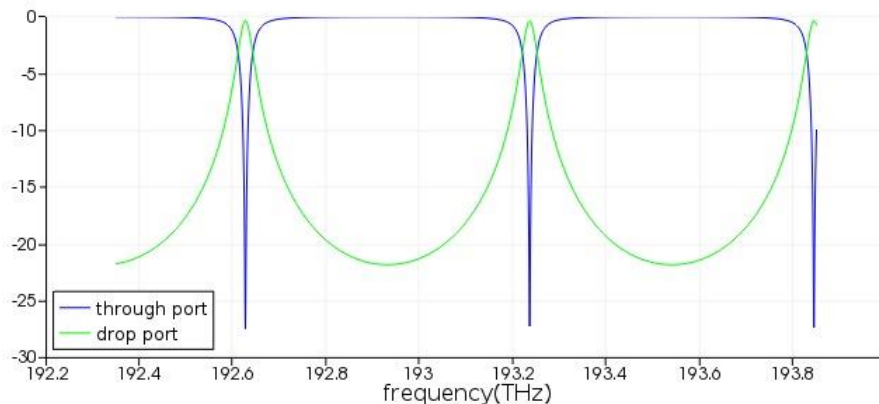


EBeam CML (passive)



Tutorial 1 – Getting Started

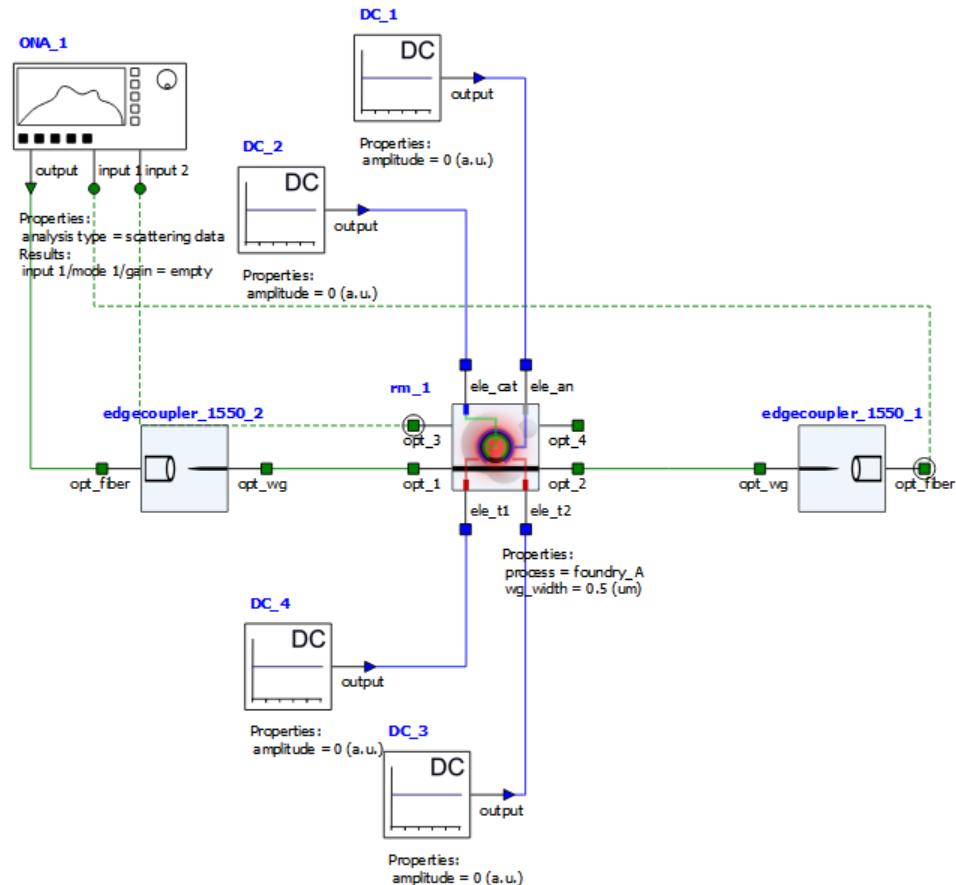
- Start application
- Create basic circuit
- Set properties
- Run simulation
- Visualize results
- Script



Frequency analysis

Create a simple circuit by drag and dropping components from the GSiP and the primitive element library.

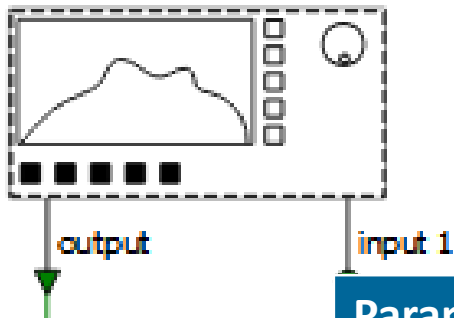
- From the primitive element library
 - ONA – optical network analyzer
- From the GSiP
 - Ring_Modulator_DB
 - Edge_coupler_1550
 - dcsource



Optical Network Analyzer

Use the following settings for the ONA (make sure the ONA is selected – dashed outline)

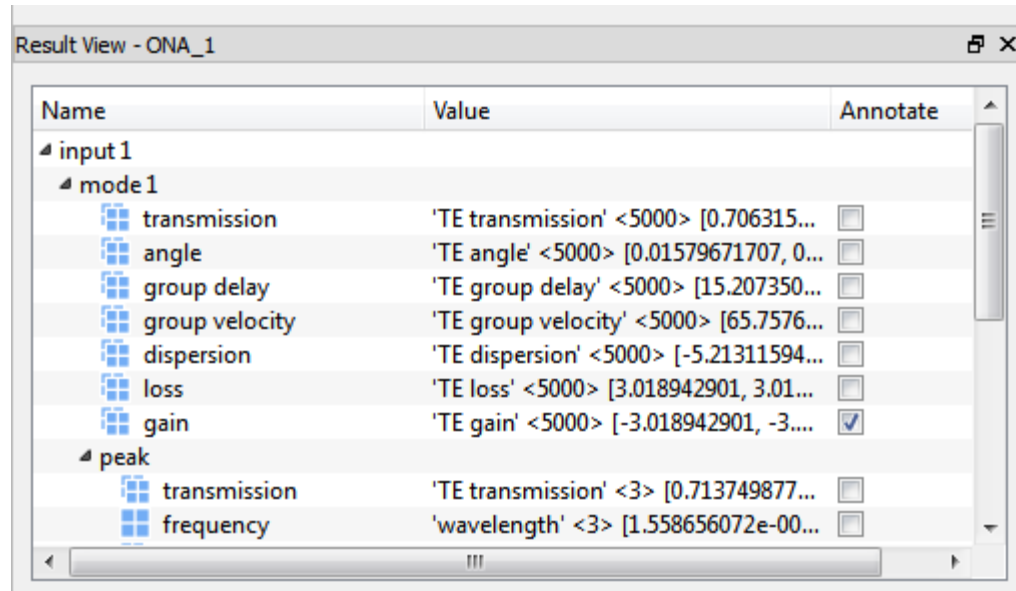
ONA_1



Parameter	value
Input parameter	Center and range
Center frequency	1550 [nm]
Frequency range	40 [nm]
Number of points	5000
Plot kind	wavelength
Number of input ports	2

Optical Network Analyzer

- Run a frequency analysis by clicking the green triangle
 - After a successful run the triangle should point the other direction
- Select the ONA (dashed outline) and find the result view window



The screenshot shows a window titled 'Result View - ONA_1'. It contains a table with three columns: 'Name', 'Value', and 'Annotate'. The table is organized into a tree structure with expandable sections: 'input 1', 'mode 1', and 'peak'. Under 'mode 1', there are several parameters including transmission, angle, group delay, group velocity, dispersion, loss, and gain. Under 'peak', there are parameters for transmission and frequency. The 'gain' parameter under 'mode 1' has a checkmark in the 'Annotate' column.

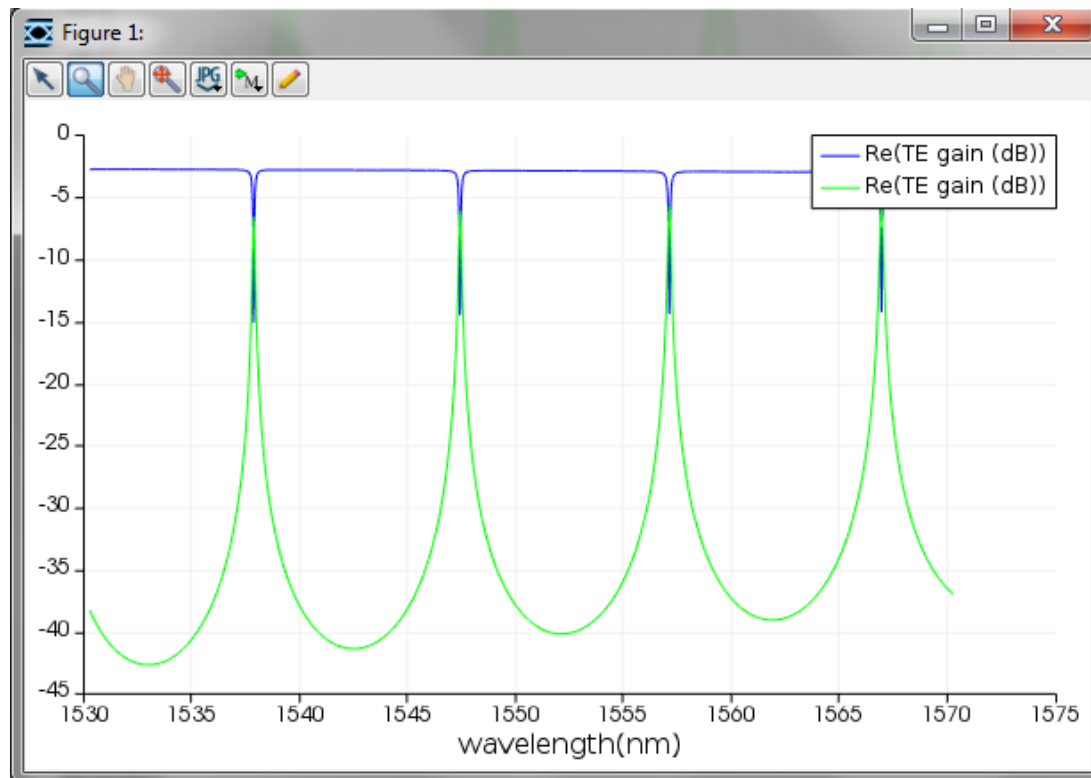
Name	Value	Annotate
input 1		
mode 1		
transmission	'TE transmission' <5000> [0.706315...	<input type="checkbox"/>
angle	'TE angle' <5000> [0.01579671707, 0...	<input type="checkbox"/>
group delay	'TE group delay' <5000> [15.207350...	<input type="checkbox"/>
group velocity	'TE group velocity' <5000> [65.7576...	<input type="checkbox"/>
dispersion	'TE dispersion' <5000> [-5.21311594...	<input type="checkbox"/>
loss	'TE loss' <5000> [3.018942901, 3.01...	<input type="checkbox"/>
gain	'TE gain' <5000> [-3.018942901, -3....	<input checked="" type="checkbox"/>
peak		
transmission	'TE transmission' <3> [0.713749877...	<input type="checkbox"/>
frequency	'wavelength' <3> [1.558656072e-00...	<input type="checkbox"/>

- Right click on gain and select visualize

Optical network analyzer

Multiple results can be send to the same visualizer

- Add the gain spectrum of the drop port to the same visualizer



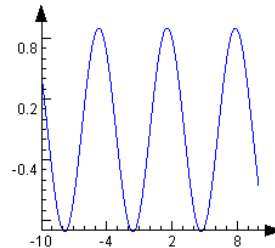
Scripting: Mathematics

Simple Mathematics: plot some simple functions

```
> x=linspace(-10,10,500);
```

```
> y=sin(x);
```

```
> plot(x,y);
```



```
> y2=exp(-x^2/9)*sin(10*x);
```

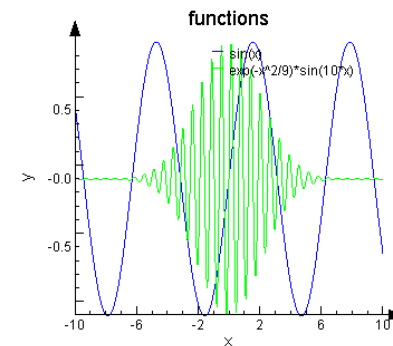
```
> plot(x,y,y2,"x","y","functions");
```

```
> legend("sin(x)","exp(-x^2/9)*sin(10*x)");
```

```
> ?size(x);
```

result:

500 1



Frequency analysis

Free spectral range

```
Script Prompt
> ?c/3.918/(2*pi*20e-6);
result:
6.08901e+011
>
```

$$\Delta v = \frac{c}{n_g l}$$

Peak analysis

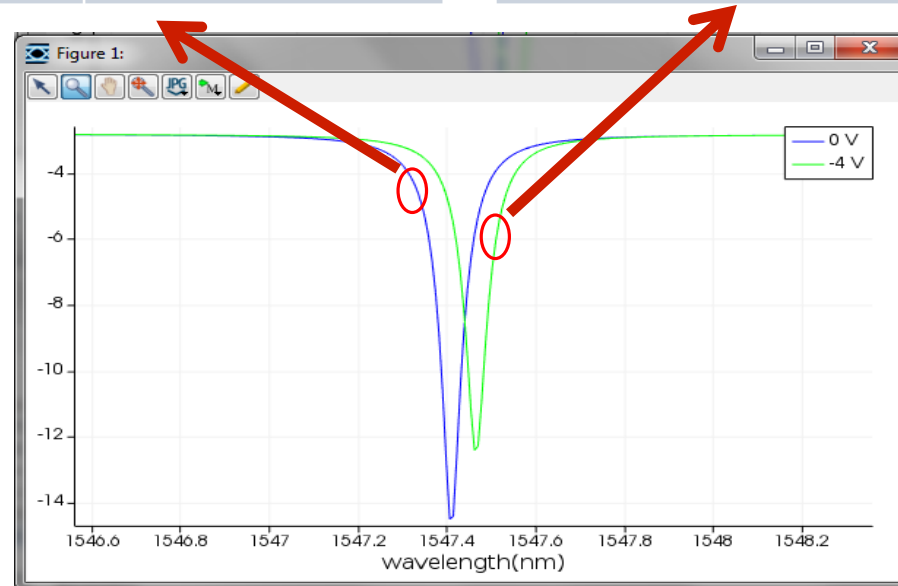
```
Script Prompt
> ?getresult;
ONA_1
> ?R = getresult("ONA_1", "input 1/mode 1/peak/free spectral range");
TE free spectral range (Hz) vs frequency
> ?R.getattribute("TE free spectral range (Hz)");
result:
6.08822e+011
6.09122e+011
6.09122e+011
> |
```

Frequency analysis

- Run the simulation twice with the DC source amplitude equals 0 and 4, respectively (applied to the anode of the modulator). Plot the gain curves in one figure.

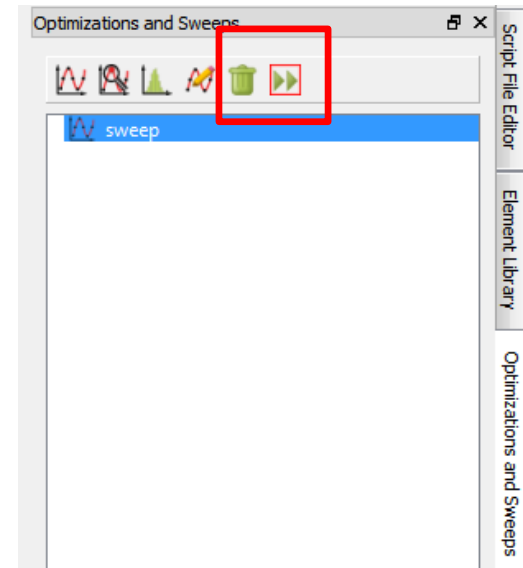
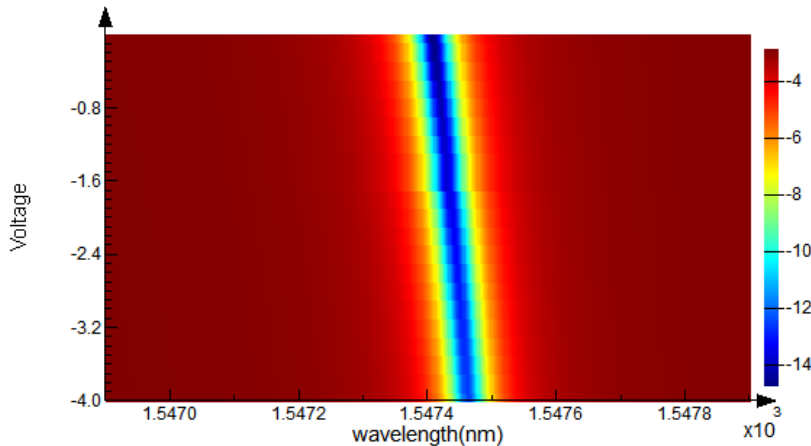
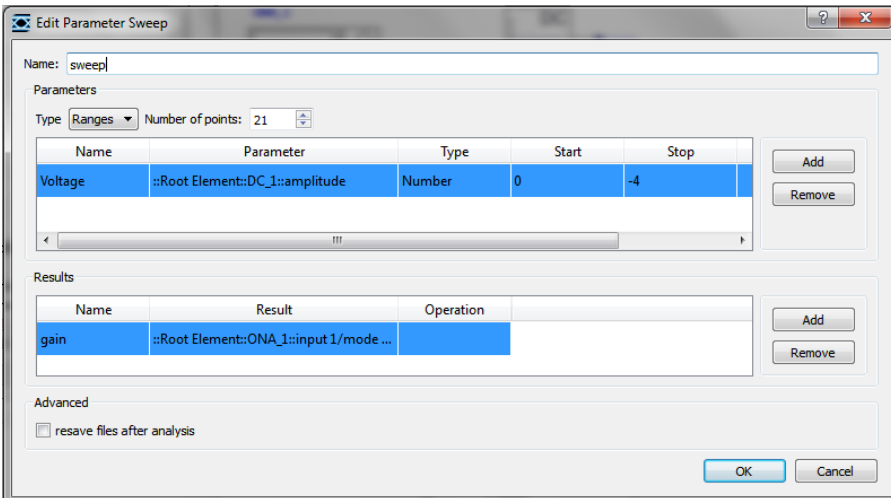
DC_1 Property	Value
Amplitude	0

DC_1 Property	Value
Amplitude	-4



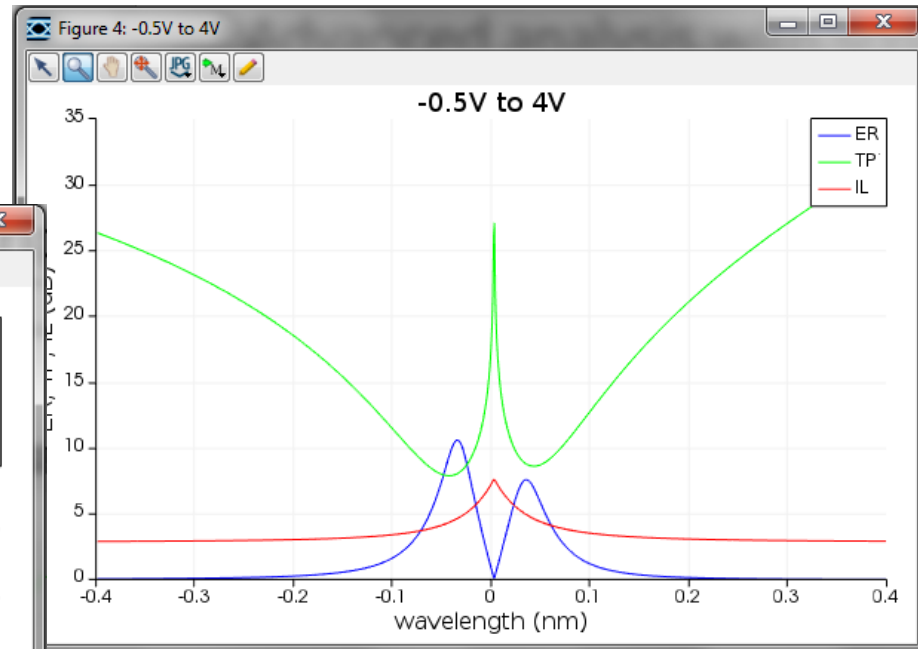
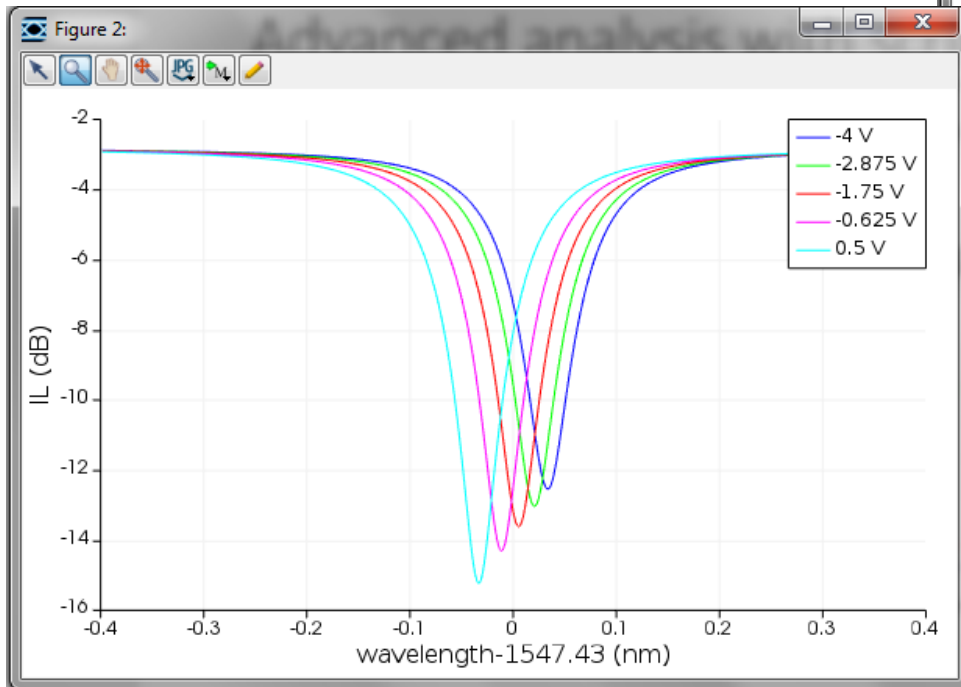
Sweep framework

- DC_1 amplitude: from 0 to 4V
- Transmission at center (1547.4 nm)
- Change the center wavelength of the ONA to 1547.4 nm and the range to 1nm
- Run the sweep
- Right click on sweep to visualize



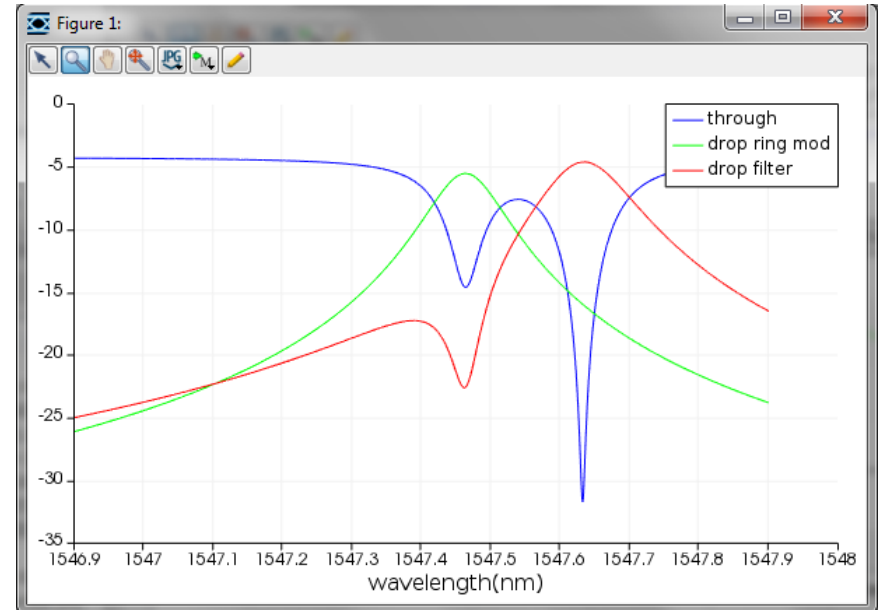
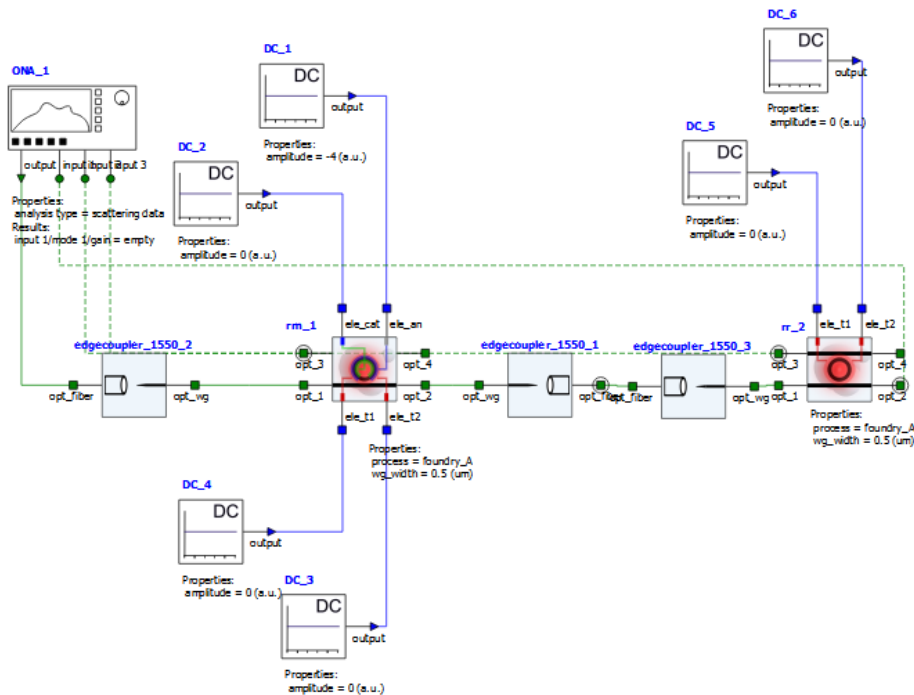
Advanced analysis with scripting

- Run the script 'ring_mod_characterization.lsf' to further analyze the ring modulator performance



Frequency analysis

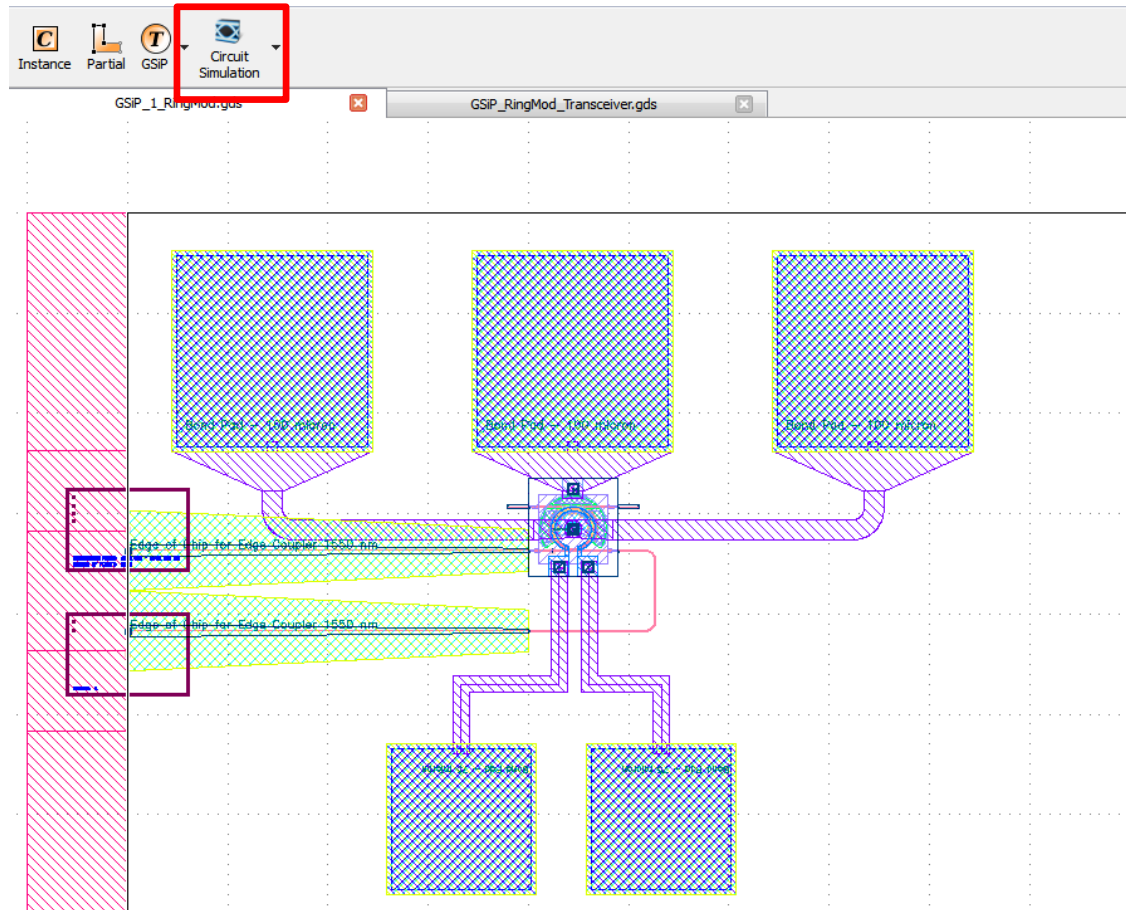
Ring modulator + drop filter (gap = 300nm and monitor gap = 310nm)



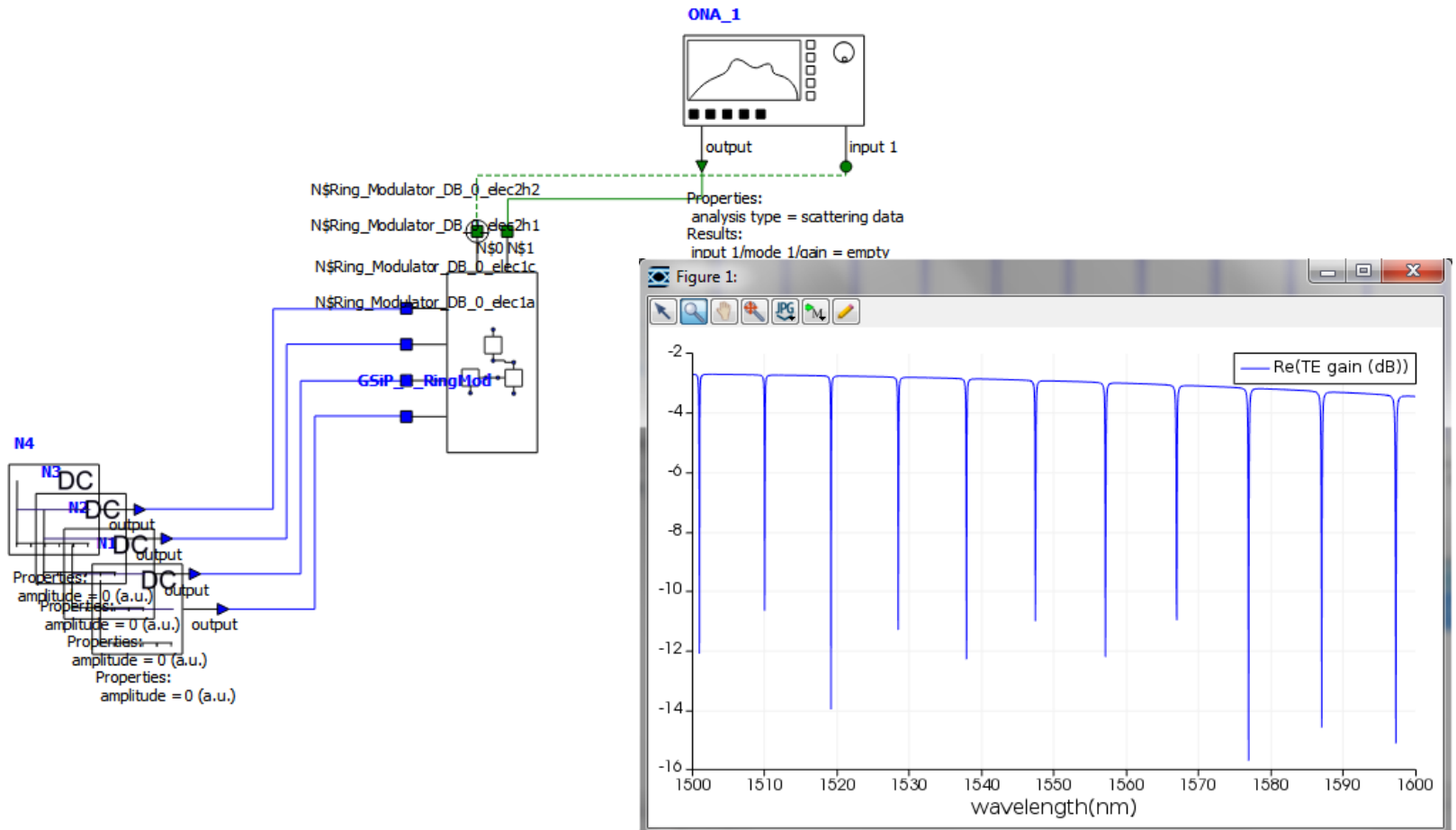
Tutorial 2 – Transient Analysis

Layout driven simulation

Export netlist and launch INTERCONNECT

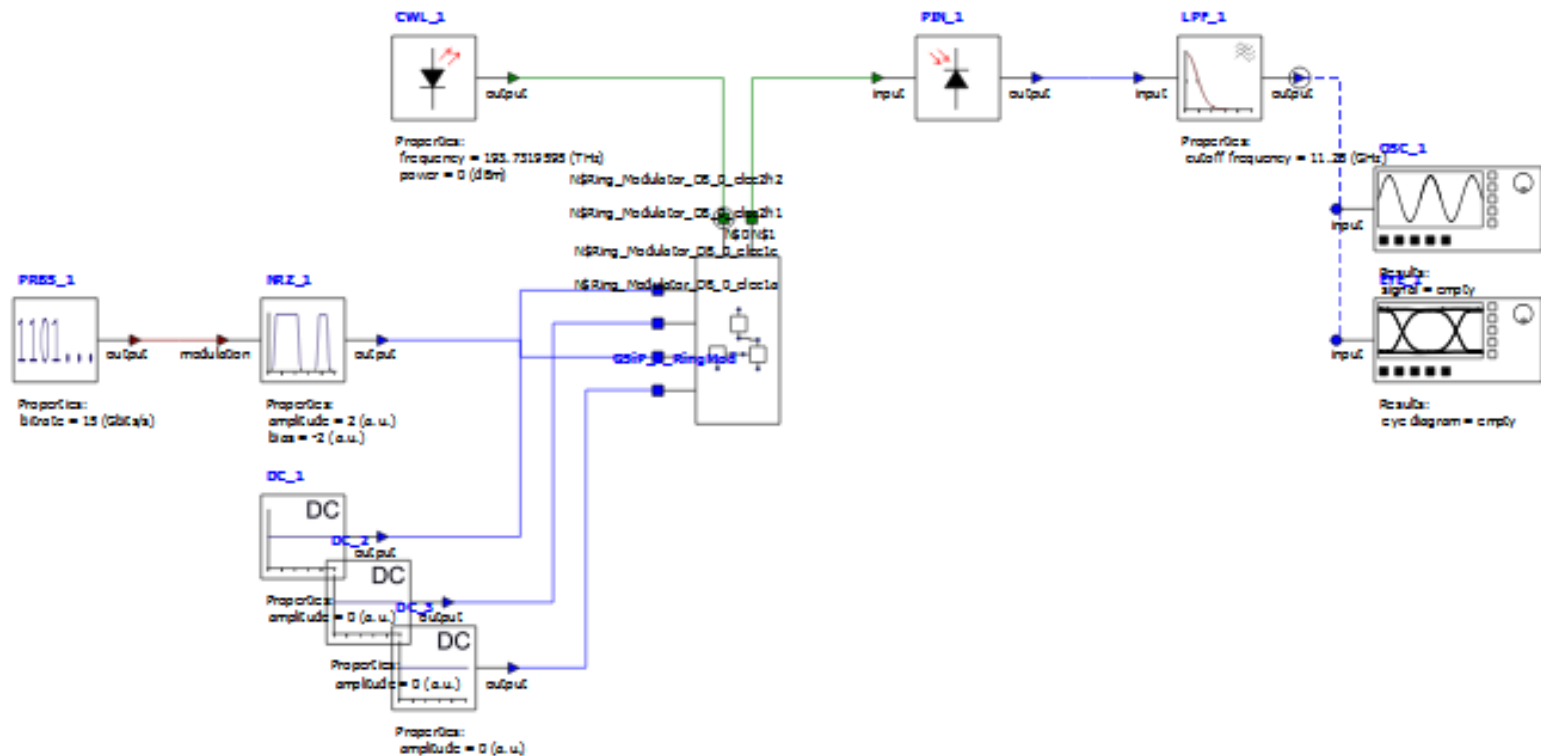


Frequency analysis

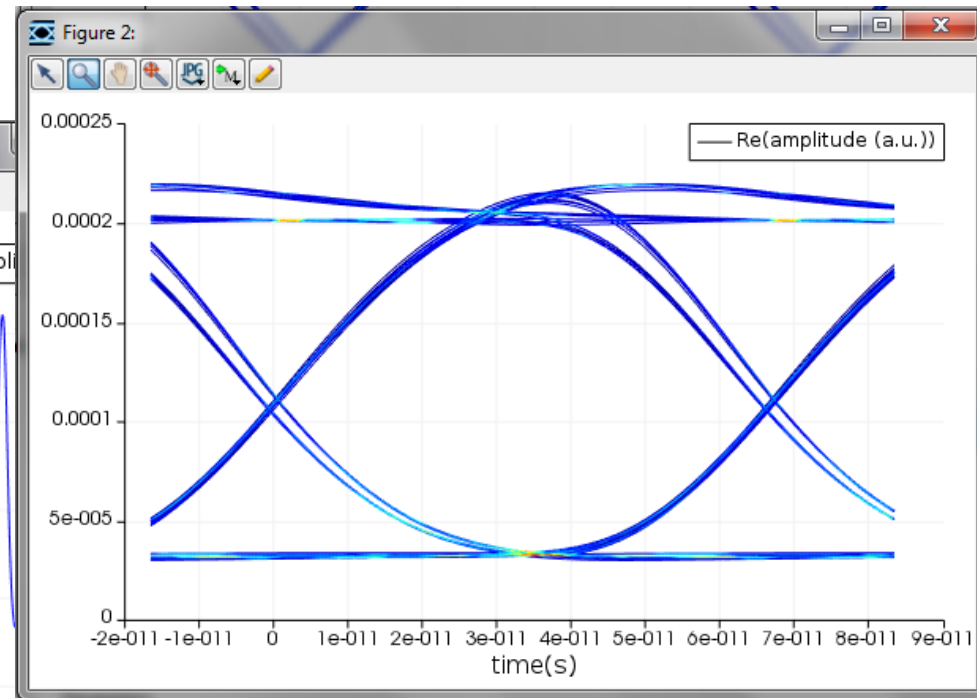
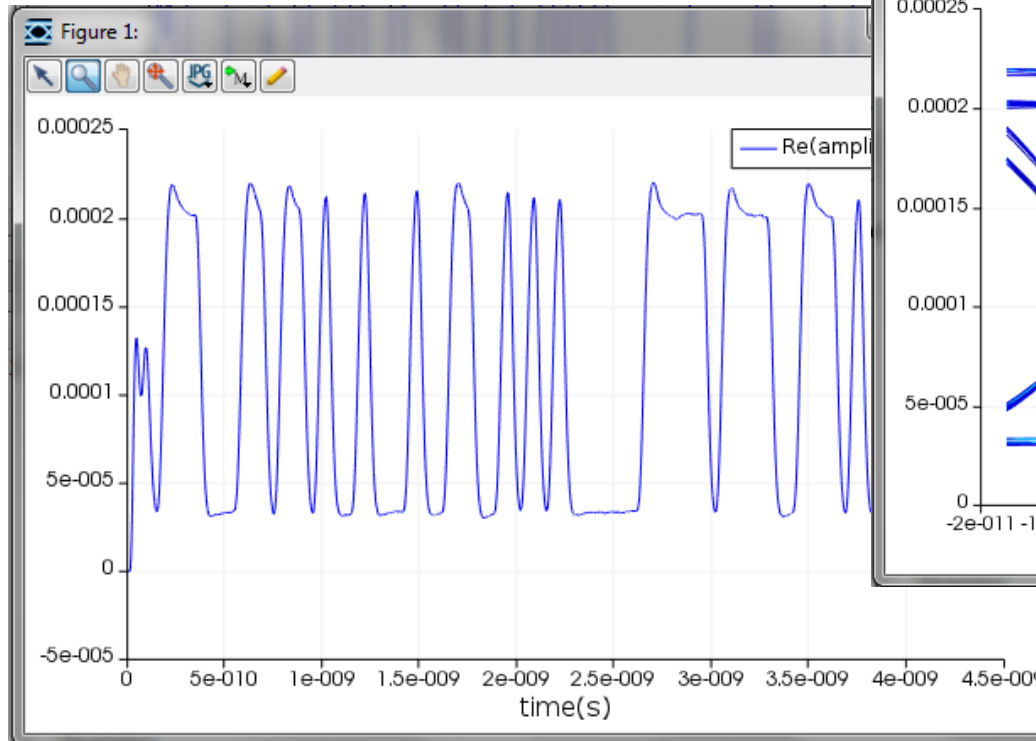


Time domain test bench

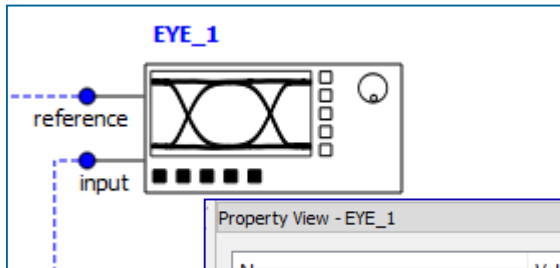
- Run the script 'Time_domain_testbench_single_modulator.isf' to convert the frequency domain testbench into a time domain testbench



Time domain results



Time domain – result analysis



Property View - EYE_1

Name	Value	Unit	Expression
<input checked="" type="checkbox"/> signal reference input	true		
<input checked="" type="checkbox"/> eye period	1.5	bit p...	
<input checked="" type="checkbox"/> ignore start periods	8		
<input checked="" type="checkbox"/> ignore end periods	8		
<input checked="" type="checkbox"/> delay compensation	automatic		
<input checked="" type="checkbox"/> delay	0	s	
Enhanced			
<input checked="" type="checkbox"/> color grading	false		
<input checked="" type="checkbox"/> binning size	500		
<input checked="" type="checkbox"/> smoothness	10		
<input checked="" type="checkbox"/> random sampling	false		
<input checked="" type="checkbox"/> time unit	s		
<input checked="" type="checkbox"/> decision point	automatic		
<input checked="" type="checkbox"/> decision instant	2e-10	s	
<input checked="" type="checkbox"/> threshold	0	a.u.	
<input checked="" type="checkbox"/> BER estimation	Gaussian		
<input checked="" type="checkbox"/> calculate measurements	true		
<input checked="" type="checkbox"/> calculate graphs	true		
<input checked="" type="checkbox"/> eye opening tolerance	0	ratio	
<input checked="" type="checkbox"/> plot waveforms	true		
Display			
<input checked="" type="checkbox"/> refresh	true		
<input checked="" type="checkbox"/> refresh length	8192		
<input checked="" type="checkbox"/> limit display memory	true		
<input checked="" type="checkbox"/> display memory length	2048		

Result View - EYE_1

Name	Value	Annotate
eye diagram	'amplitude' <4512,1> [0.0009687698296, 0.0009580644452, 0.0009...	<input checked="" type="checkbox"/>
measurement		
decision instant	'time' 0.25e-009 (s)	<input type="checkbox"/>
threshold	'amplitude' 0.0004995075353 (a.u.)	<input type="checkbox"/>
level zero mean	'amplitude' -4.450158418e-006 (a.u.)	<input type="checkbox"/>
level zero sigma	'amplitude' 4.067774101e-006 (a.u.)	<input type="checkbox"/>
level one mean	'amplitude' 0.001004248213 (a.u.)	<input type="checkbox"/>
level one sigma	'amplitude' 4.210775934e-006 (a.u.)	<input type="checkbox"/>
BER	'BER' 0	<input type="checkbox"/>
Q factor	'ratio' 121.8448118	<input type="checkbox"/>
height	'amplitude' 0.0009838627211 (a.u.)	<input type="checkbox"/>
amplitude	'amplitude' 0.001008698371 (a.u.)	<input type="checkbox"/>
extinction ratio	'ratio' 23.53465596 (dB)	<input type="checkbox"/>
opening factor	'ratio' 0.9917928389	<input type="checkbox"/>
width	'time' 0.3993955507e-009 (s)	<input type="checkbox"/>
pulse width	'time' 0.4001714451e-009 (s)	<input type="checkbox"/>
jitter RMS	'time' 0.1471843164e-012 (s)	<input type="checkbox"/>
peak to peak jitter	'time' 0.6145806978e-012 (s)	<input type="checkbox"/>
rise time	'time' 0.1899530508e-009 (s)	<input type="checkbox"/>
fall time	'time' 89.61706091e-012 (s)	<input type="checkbox"/>
graph		
threshold at min BER	'amplitude' <64,1> [0.0005098341574, 0.0005084810127, 0.000507...	<input type="checkbox"/>
min BER	'BER' <64,1> [0.1564401769, 0.1236627777, 0.09283178859...]	<input type="checkbox"/>
Q factor	'ratio' <64,1> [1.008941367, 1.156647113, 1.32322107...]	<input type="checkbox"/>
level zero mean	'amplitude' <64,1> [0.0002619076763, 0.000244546129, 0.0002275...	<input type="checkbox"/>
level zero sigma	'amplitude' <64,1> [0.0002403628896, 0.0002243774077, 0.000208...	<input type="checkbox"/>
level one mean	'amplitude' <64,1> [0.0007476196707, 0.0007643344799, 0.000780...	<input type="checkbox"/>
level one sigma	'amplitude' <64,1> [0.000241044663, 0.0002250149308, 0.0002093...	<input type="checkbox"/>
height	'amplitude' <64,1> [-0.0009585106635, -0.0008283886645, -0.0007...	<input type="checkbox"/>
amplitude	'amplitude' <64,1> [0.0004857119944, 0.0005197883509, 0.000553...	<input type="checkbox"/>
extinction ratio	'ratio' <64,1> [2.854516069, 3.12552271, 3.431288405...]	<input type="checkbox"/>
opening factor	'ratio' <64,1> [0.008862127813, 0.1354320702, 0.2443260829...]	<input type="checkbox"/>
waveform		
reference	'amplitude' <4096,1> [0, 0, 0...]	<input type="checkbox"/>
correlation	'amplitude' <4096,1> [0.0003806109164, 0.0003764310337, 0.0003...	<input type="checkbox"/>
input	'amplitude' <4096,1> [-3.487493865e-018, -3.284639609e-018, -3....]	<input type="checkbox"/>
bit pattern	'amplitude' <4096,1> [0, 0, 0...]	<input type="checkbox"/>

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