



# SC454 Silicon Photonics Circuits and Systems Design

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OFC SHORT COURSE MARCH – 20<sup>TH</sup>, 2017



# INTERCONNECT GUI

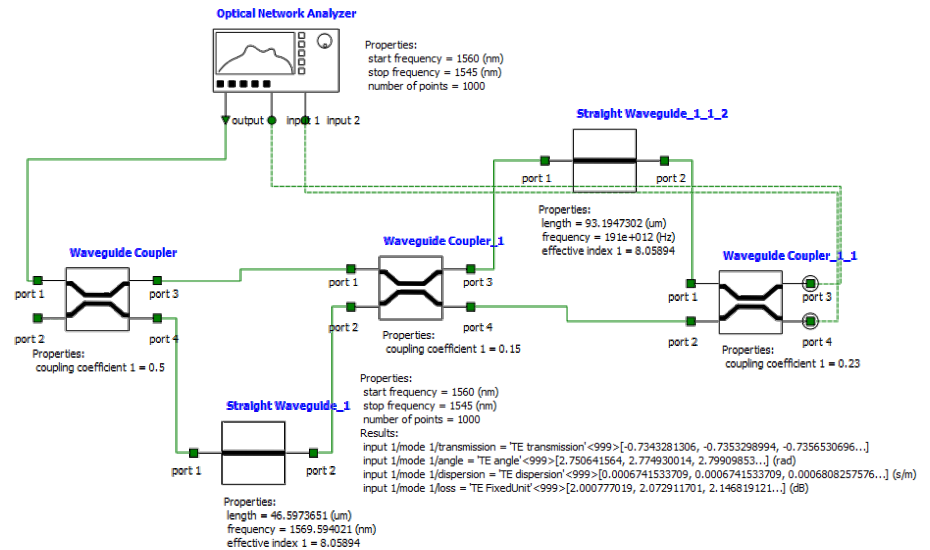
The screenshot displays the Lumerical INTERCONNECT GUI interface, which is used for simulating optical networks. The interface is divided into several main sections, each labeled with a red arrow and text:

- Run**: Points to the 'Run' button in the top-left toolbar.
- Results**: Points to the 'Results' tab in the top-left pane.
- Properties**: Points to the 'Properties' tab in the top-left pane.
- Schematic**: Points to the main schematic workspace showing the optical network layout.
- Visualizers**: Points to the 'Visualizers' tab in the top-left pane.
- Library**: Points to the 'Element Library' pane on the right, which lists various optical components.
- Script editor**: Points to the 'Script File Editor' pane on the right, which contains a script for running the simulation.
- Element tree**: Points to the 'Element Tree' pane in the bottom-left, which shows the hierarchy of the simulation setup.
- Ports**: Points to the 'Ports' pane in the bottom-left, which lists the input and output ports of the simulation.
- Script prompt**: Points to the 'Script Prompt' pane in the bottom-left, which shows the command line for running the simulation.
- Output**: Points to the 'Output' pane in the bottom-right, which displays the results of the simulation.
- Optimizations and sweeps**: Points to the 'Optimizations and Sweeps' pane in the bottom-right, which shows the progress of the optimization process.

The central schematic workspace shows a complex optical network layout with various components like waveguides, couplers, and modulators. A plot window titled 'Figure 1' is also visible, showing the results of the simulation.

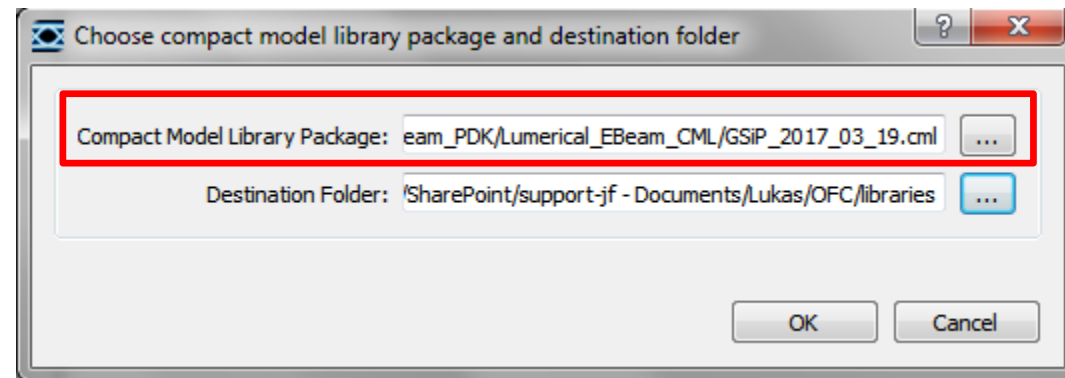
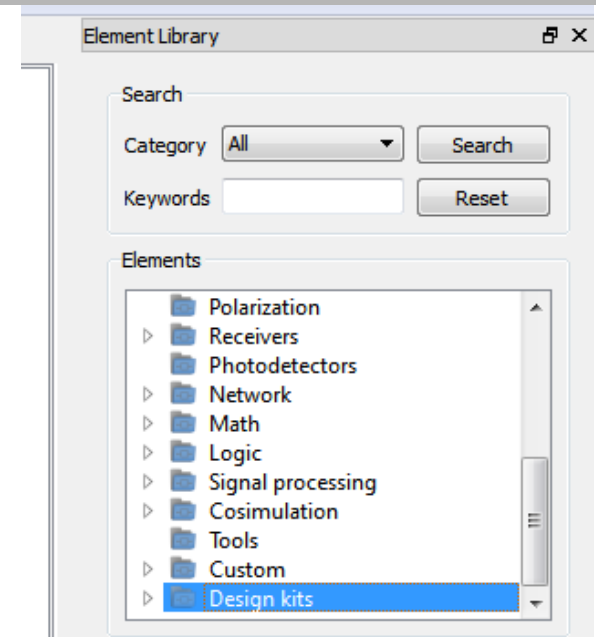
# INTERCONNECT workflow

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



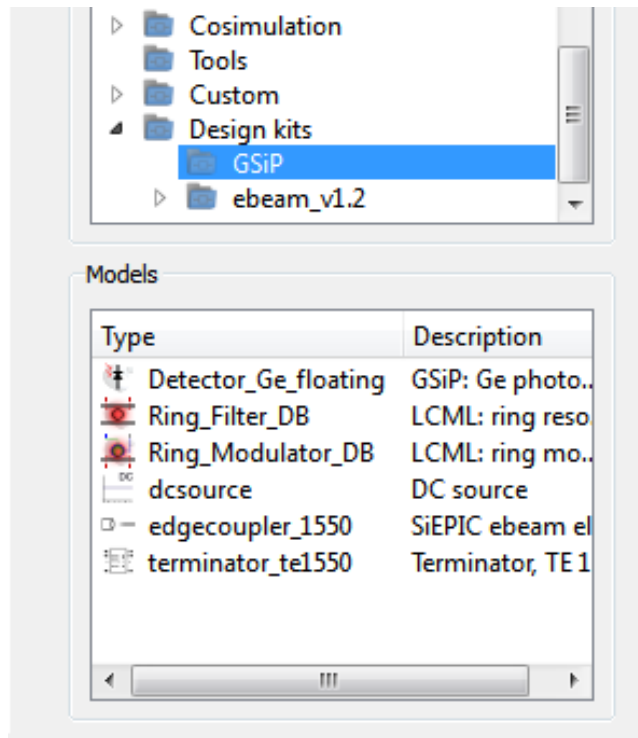
# Install a compact model library

- 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

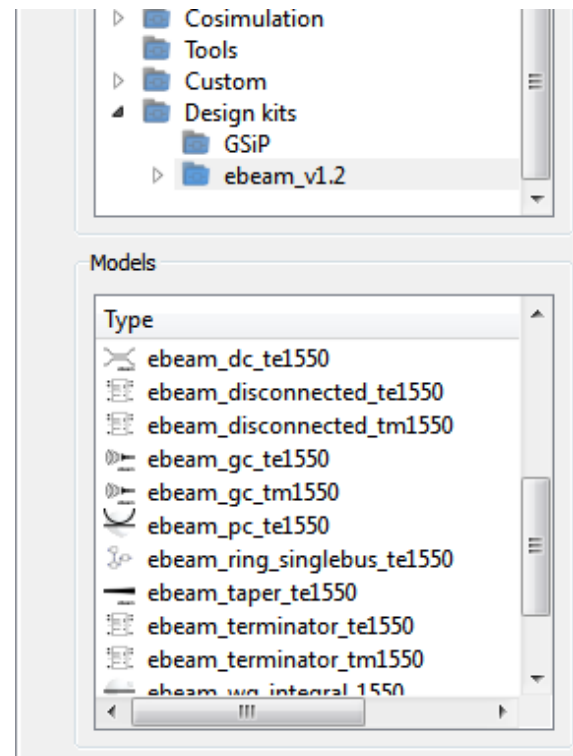


# Compact model libraries

GSiP CML (active)

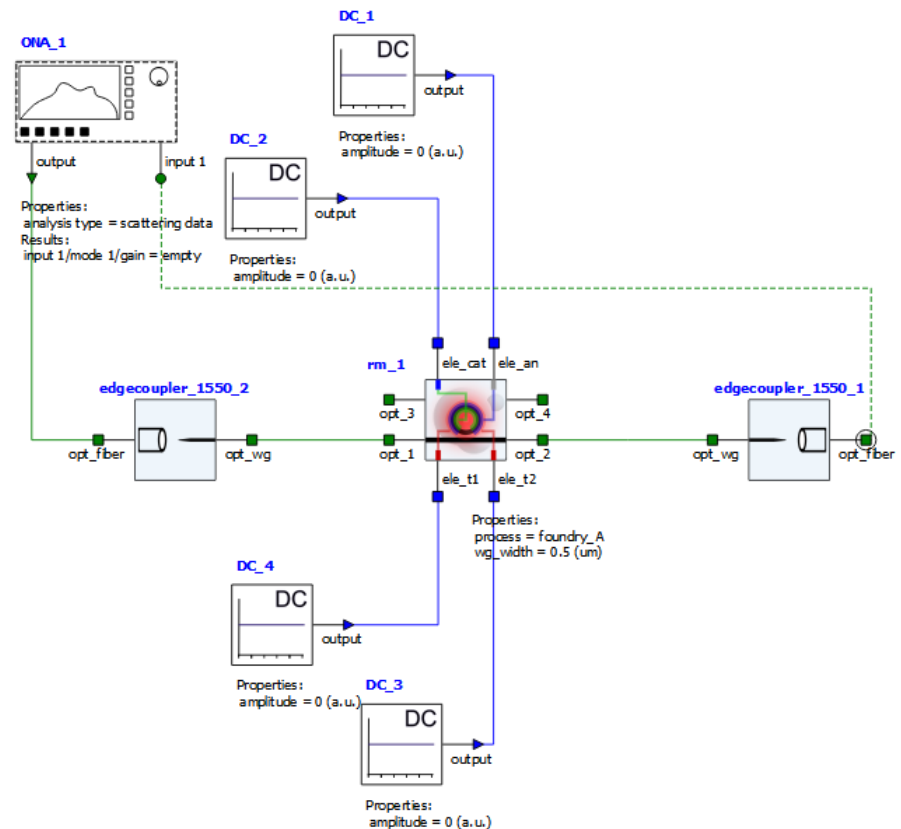
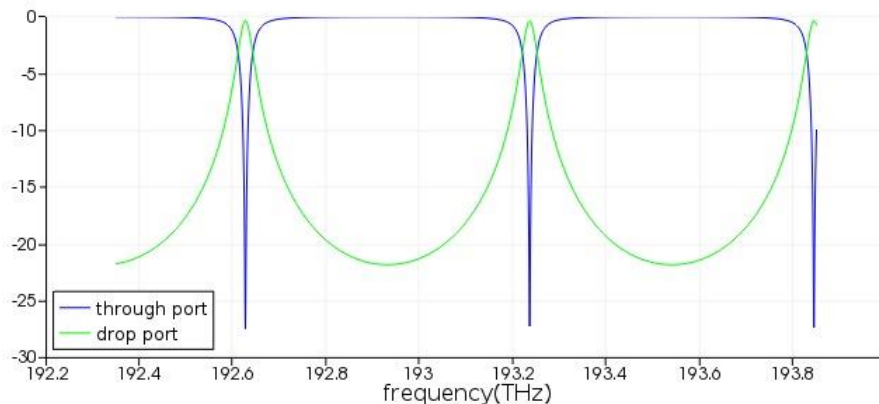


EBeam CML (passive)



# Tutorial 1 – Getting Started

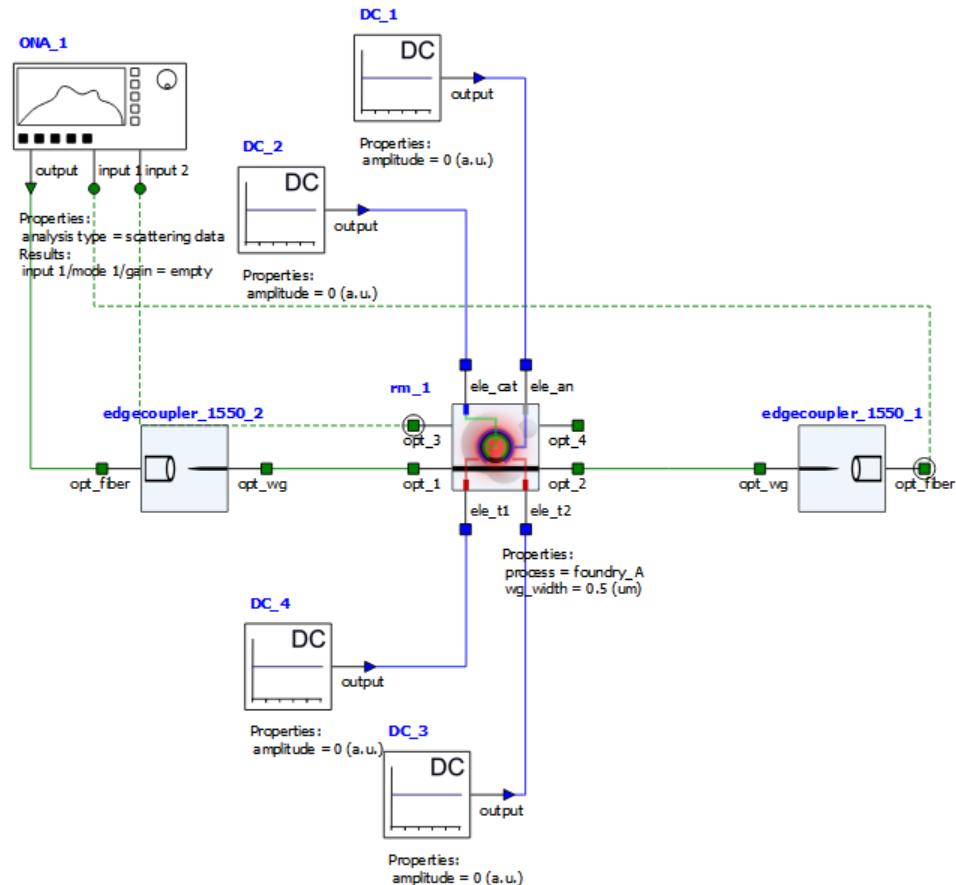
- Start application
- Create basic circuit
- Set properties
- Run simulation
- Visualize results
- Script



# Frequency analysis

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

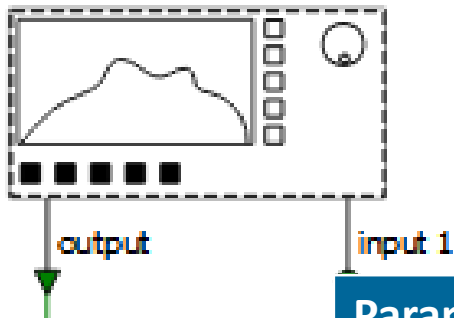
- From the primitive element library
  - ONA – optical network analyzer
- From the GSiP
  - Ring\_Modulator\_DB
  - Edge\_coupler\_1550
  - dcsource



# Optical Network Analyzer

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

ONA\_1

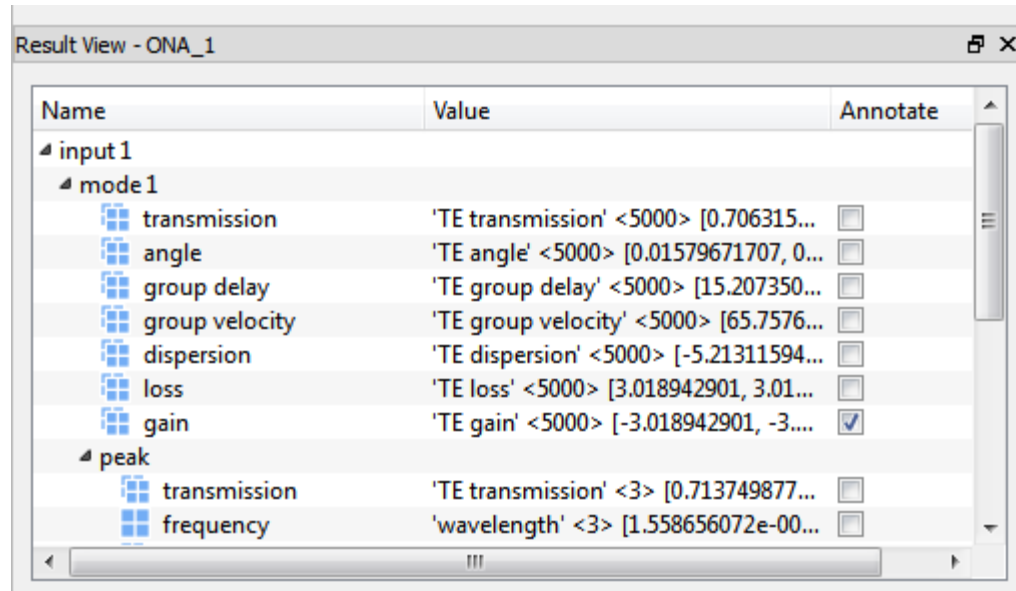


Parameter	value
Input parameter	Center and range
Center frequency	1550 [nm]
Frequency range	40 [nm]
Number of points	5000
Plot kind	wavelength
Number of input ports	2



# 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



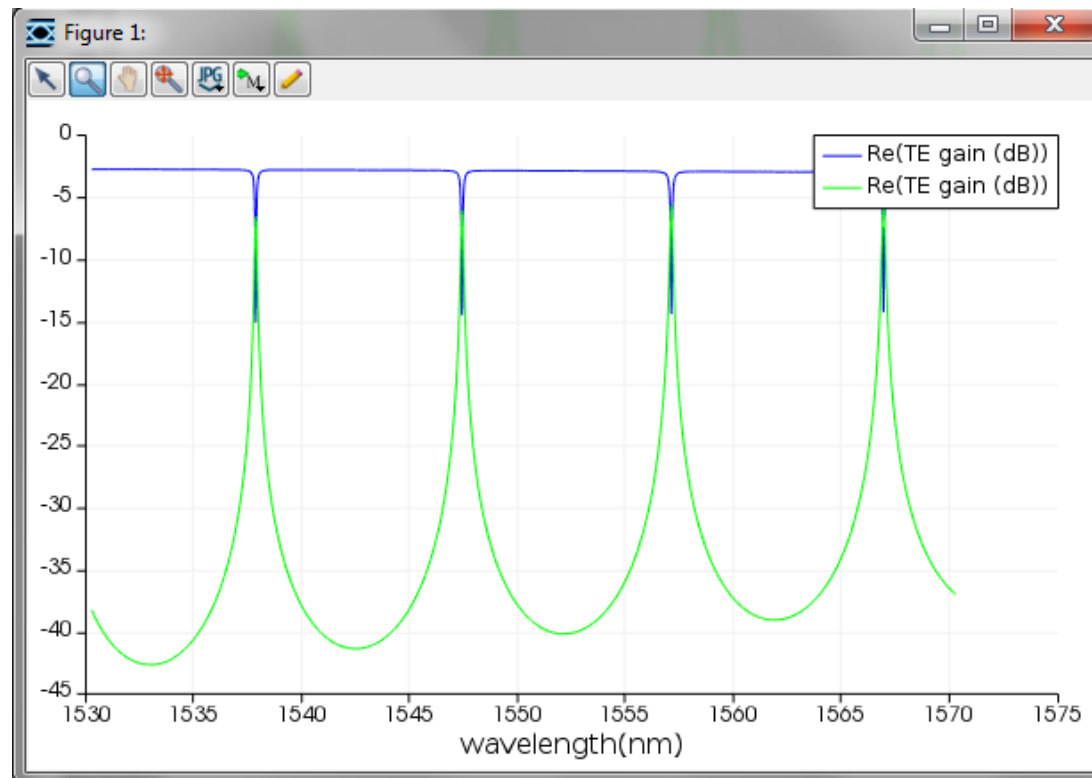
Name	Value	Annotate
input 1		
mode 1		
transmission	'TE transmission' <5000> [0.706315...	<input type="checkbox"/>
angle	'TE angle' <5000> [0.01579671707, 0...	<input type="checkbox"/>
group delay	'TE group delay' <5000> [15.207350...	<input type="checkbox"/>
group velocity	'TE group velocity' <5000> [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



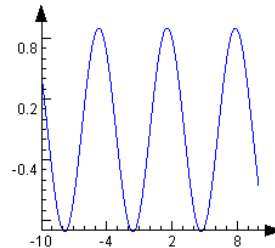
# Scripting: Mathematics

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);
```

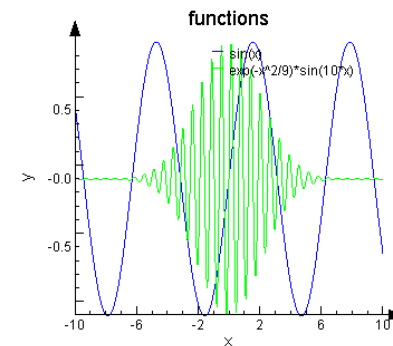
```
> plot(x,y,y2,"x","y","functions");
```

```
> 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
>
```

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

## Peak analysis

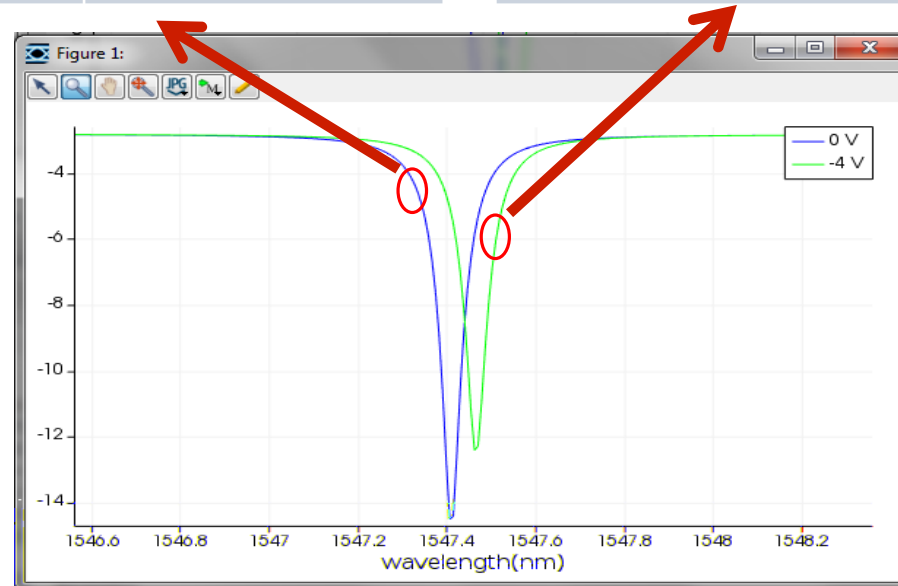
```
Script Prompt
> ?getresult;
ONA_1
> ?R = getresult("ONA_1", "input 1/mode 1/peak/free spectral range");
TE free spectral range (Hz) vs frequency
> ?R.getattribute("TE free spectral range (Hz)");
result:
6.08822e+011
6.09122e+011
6.09122e+011
> |
```

# 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.

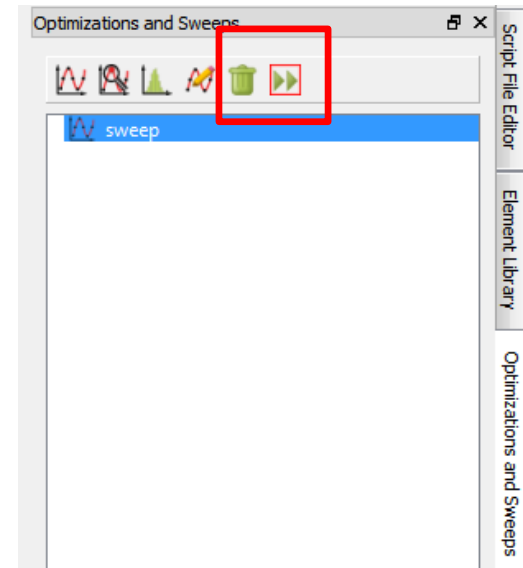
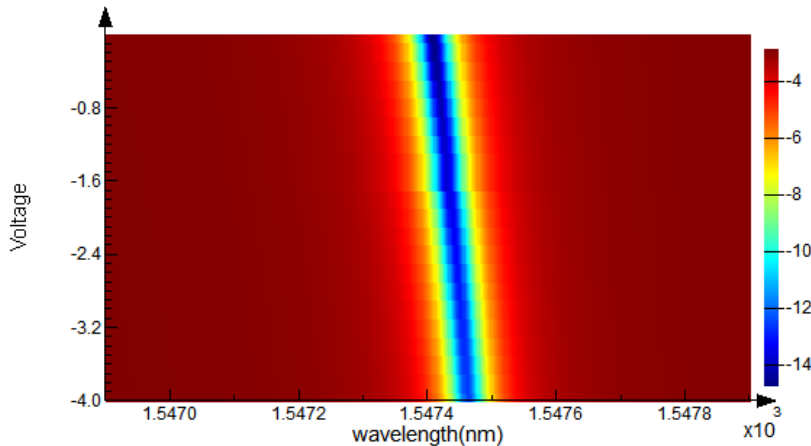
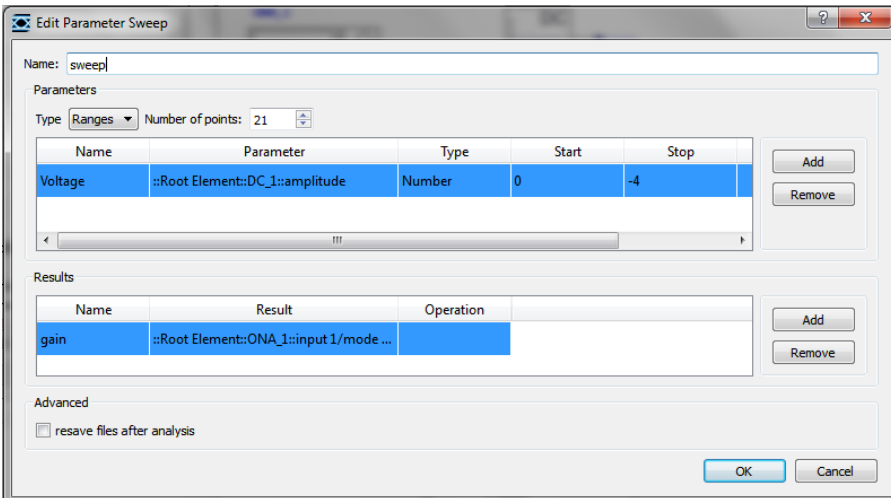
DC_1 Property	Value
Amplitude	0

DC_1 Property	Value
Amplitude	-4



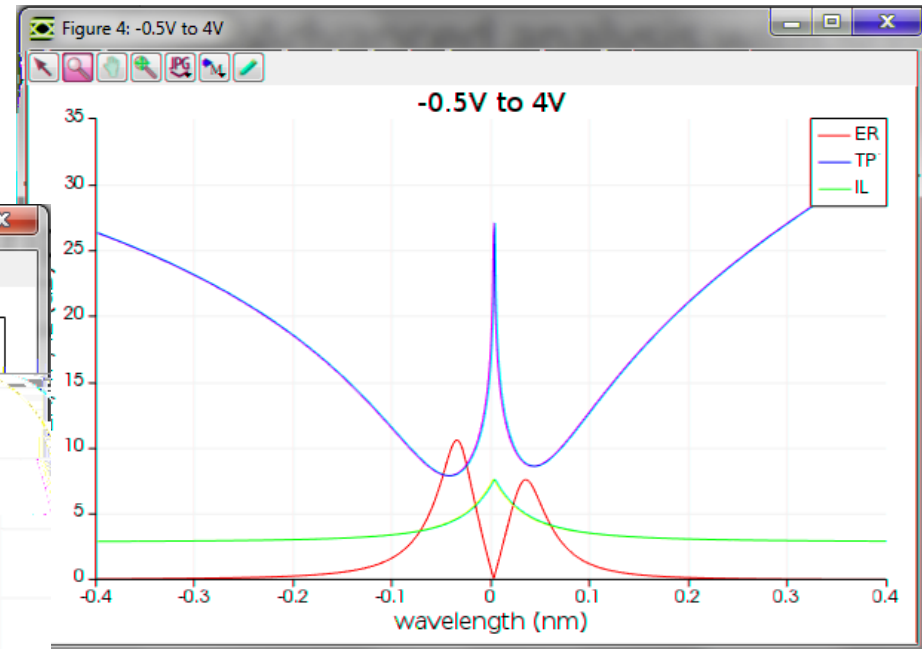
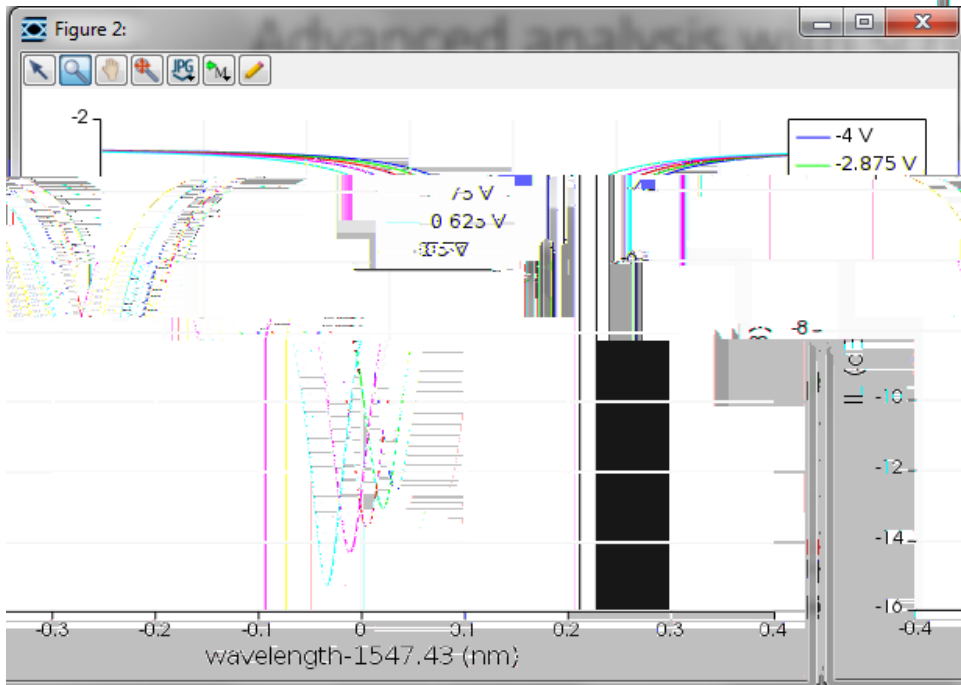
# Sweep framework

- 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



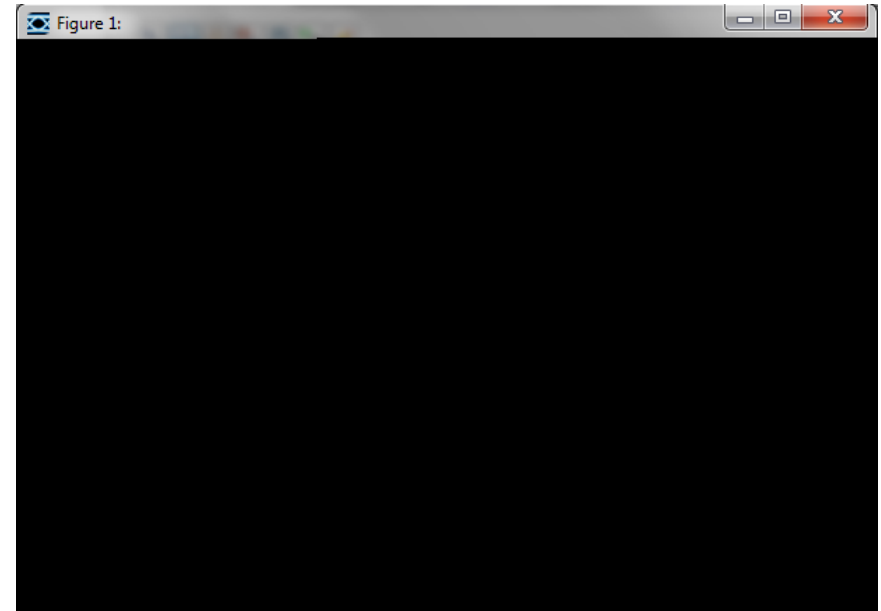
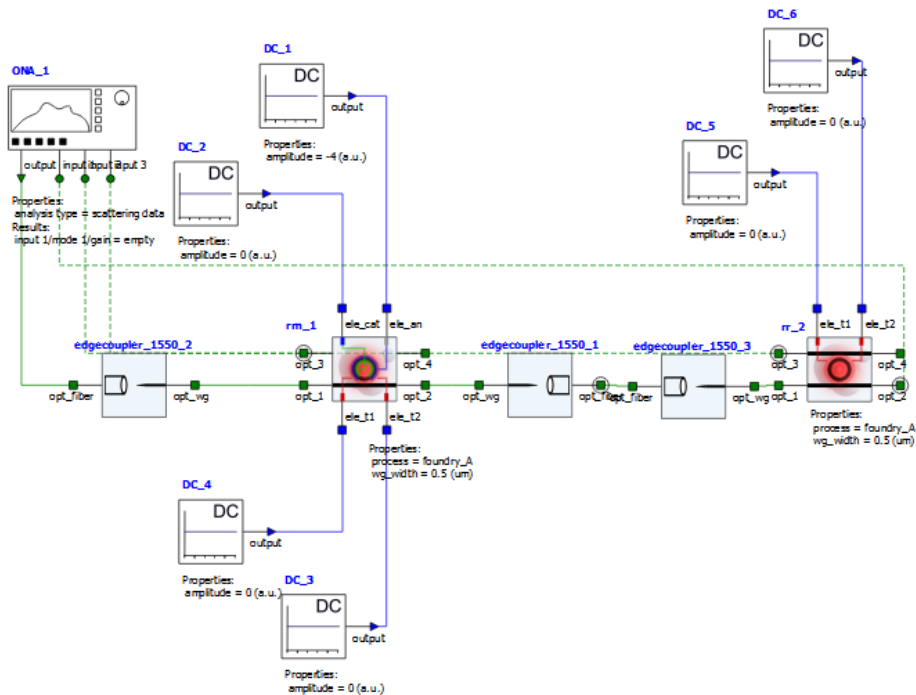
# Advanced analysis with scripting

- 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)

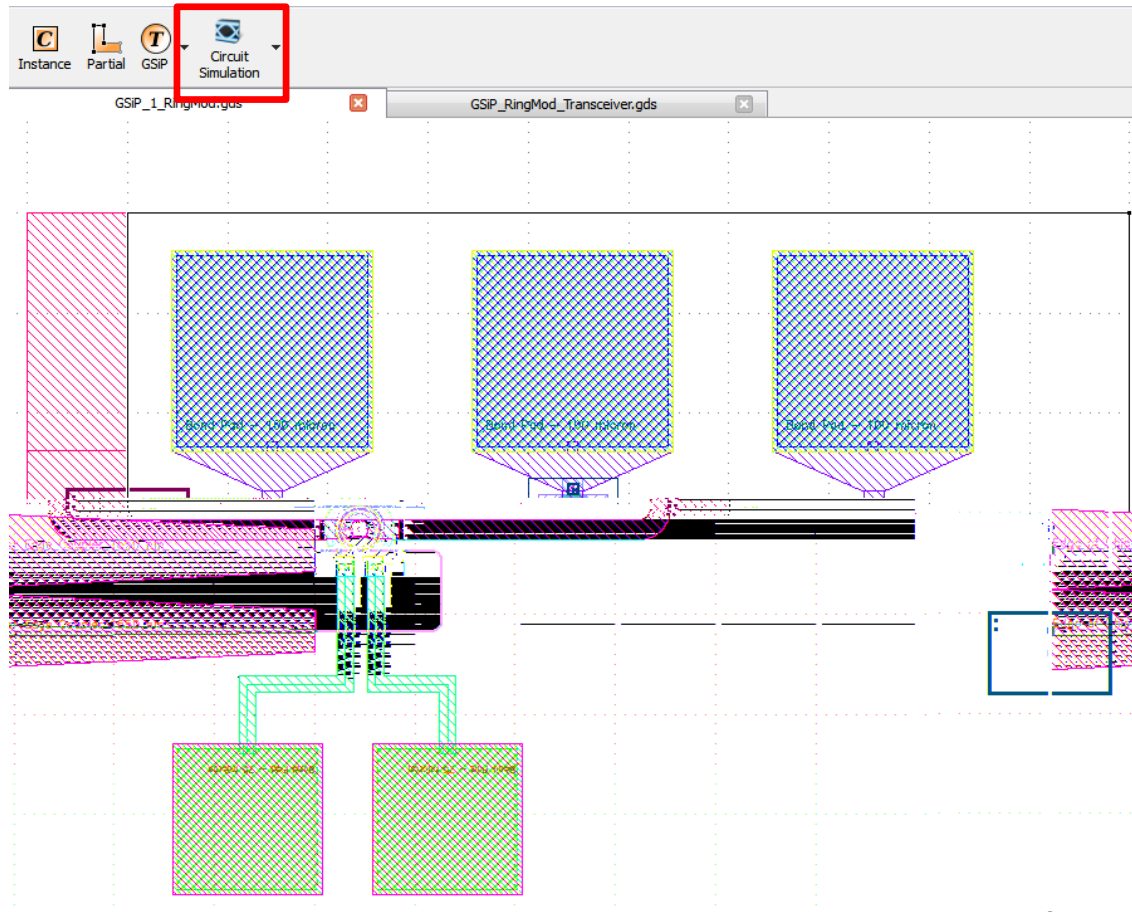




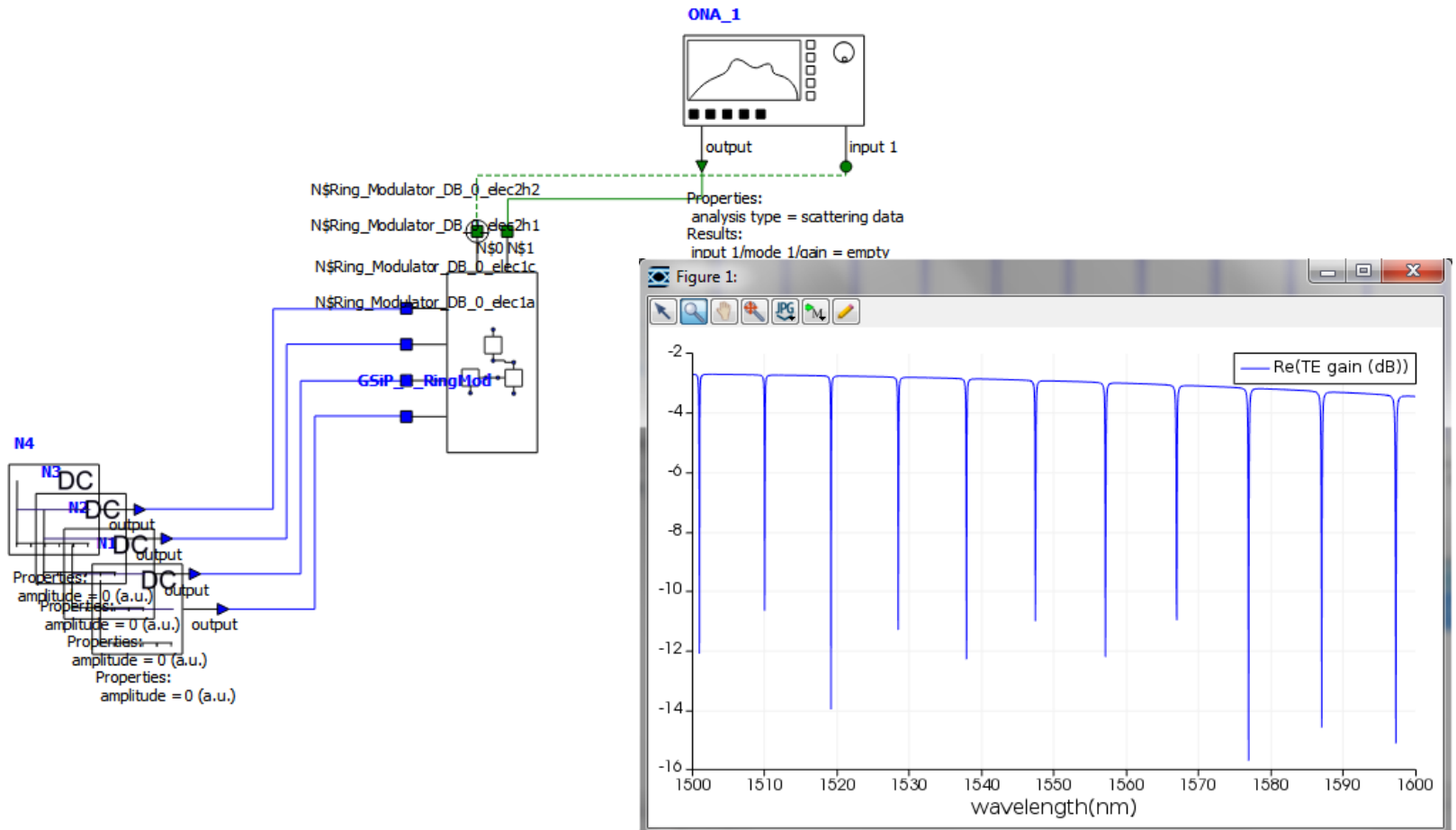
# Tutorial 2 – Transient Analysis

# Layout driven simulation

Export netlist and launch INTERCONNECT

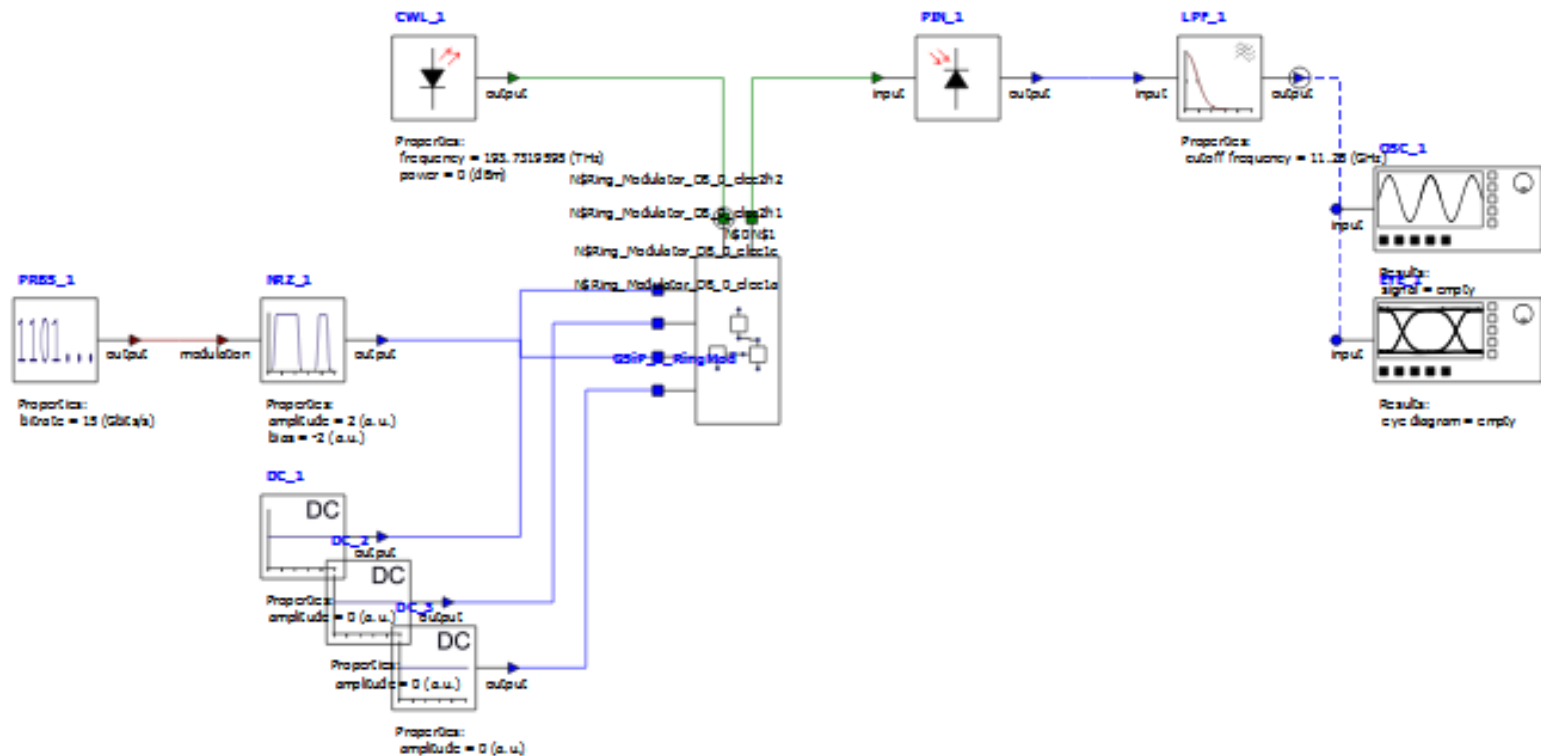


# Frequency analysis

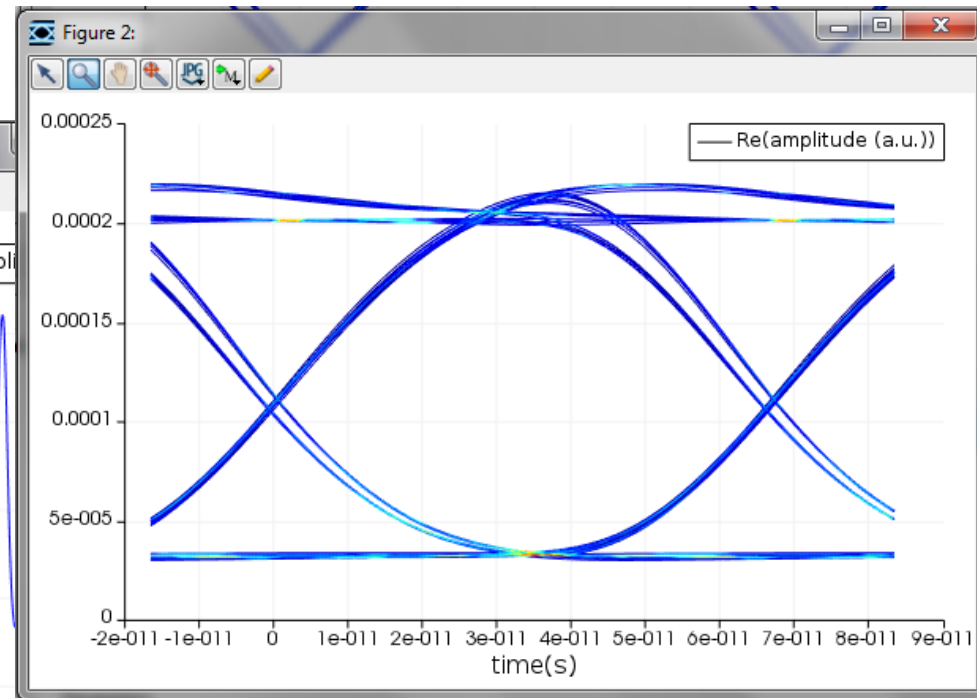
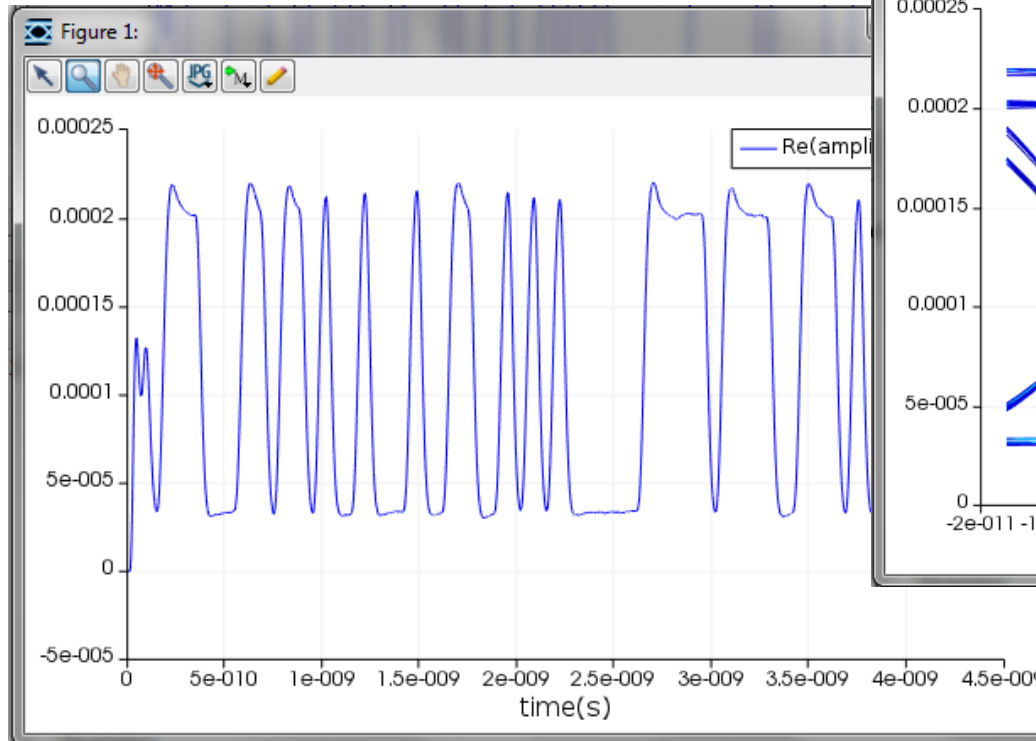


# Time domain test bench

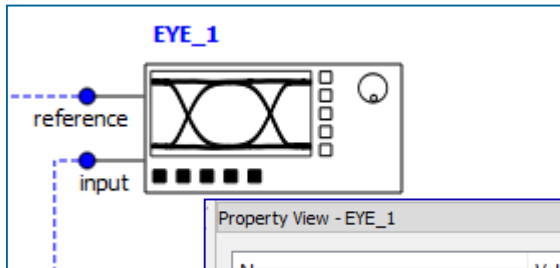
- Run the script 'Time\_domain\_testbench\_single\_modulator.isf' to convert the frequency domain testbench into a time domain testbench



# 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"/>
graph		
hold at min BER	'amplitude' <64,1> [0.0005098341574, 0.0005084810127, 0.000507...	<input type="checkbox"/>
BER	'BER' <64,1> [0.1564401769, 0.1236627777, 0.09283178859...]	<input type="checkbox"/>
tor	'ratio' <64,1> [1.008941367, 1.156647113, 1.323322107...]	<input type="checkbox"/>
zero mean	'amplitude' <64,1> [0.0002619076763, 0.000244546129, 0.0002275...	<input type="checkbox"/>
zero sigma	'amplitude' <64,1> [0.0002403628896, 0.0002243774077, 0.000208...	<input type="checkbox"/>
one mean	'amplitude' <64,1> [0.0007476196707, 0.0007643344799, 0.000780...	<input type="checkbox"/>
one sigma	'amplitude' <64,1> [0.000241044663, 0.0002250149308, 0.0002093...	<input type="checkbox"/>
it	'amplitude' <64,1> [-0.0009585106635, -0.0008283886645, -0.0007...	<input type="checkbox"/>
itude	'amplitude' <64,1> [0.0004857119944, 0.0005197883509, 0.000553...	<input type="checkbox"/>
tion ratio	'ratio' <64,1> [2.854516069, 3.12552271, 3.431288405...]	<input type="checkbox"/>
ing factor	'ratio' <64,1> [0.008862127813, 0.1354320702, 0.2443260829...]	<input type="checkbox"/>
ince	'amplitude' <4096,1> [0, 0, 0...]	<input type="checkbox"/>
lation	'amplitude' <4096,1> [0.0003806109164, 0.0003764310337, 0.0003...	<input type="checkbox"/>
	'amplitude' <4096,1> [-3.487493865e-018, -3.284639609e-018, -3...	<input type="checkbox"/>
ittern	'amplitude' <4096,1> [0, 0, 0...]	<input type="checkbox"/>
waveform		
refere	'amplitude' <4096,1> [0, 0, 0...]	<input type="checkbox"/>
corre	'amplitude' <4096,1> [0, 0, 0...]	<input type="checkbox"/>
input	'amplitude' <4096,1> [0, 0, 0...]	<input type="checkbox"/>
bit pa	'amplitude' <4096,1> [0, 0, 0...]	<input type="checkbox"/>

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