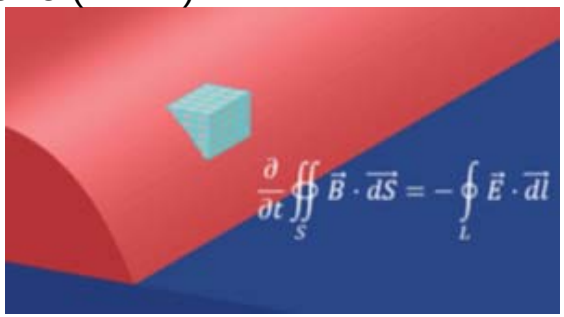
DBR LASER
INTERCONNECT Simulation

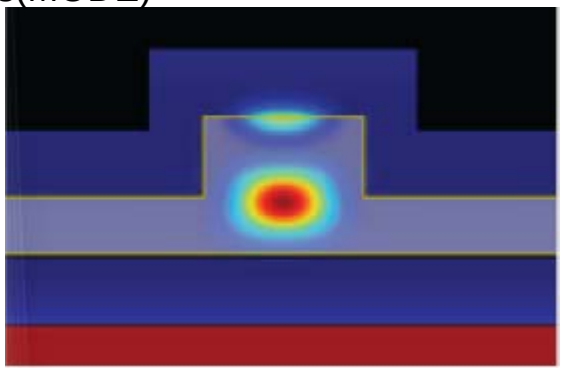
High-Speed Circuits & Systems Lab.
Dept. of Electrical and Electronic Engineering
Yonsei University

Lumerical Solutions

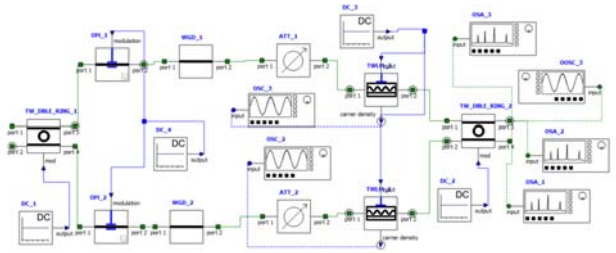
3D Maxwell solver(FDTD)



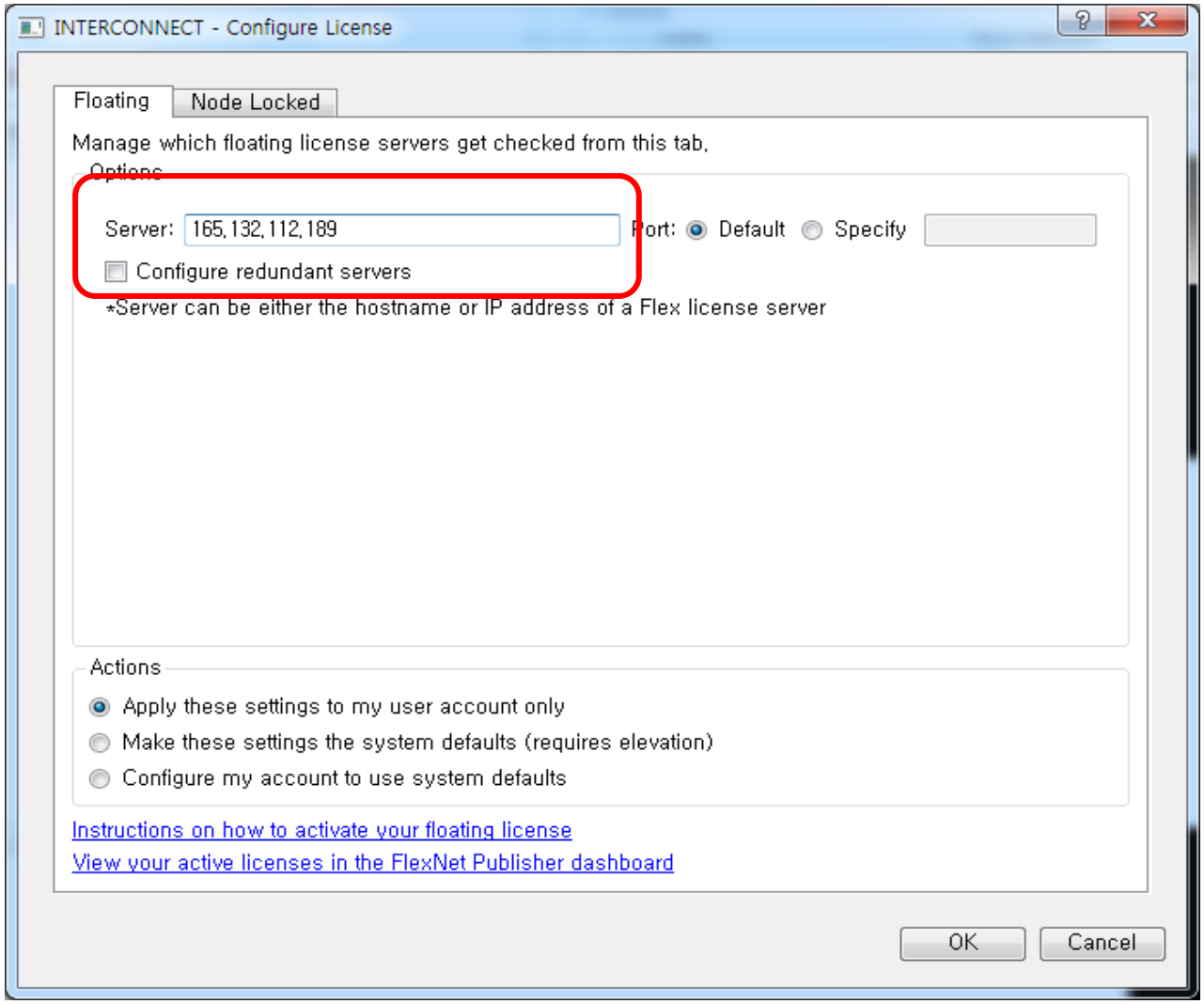
Modal analysis(MODE)



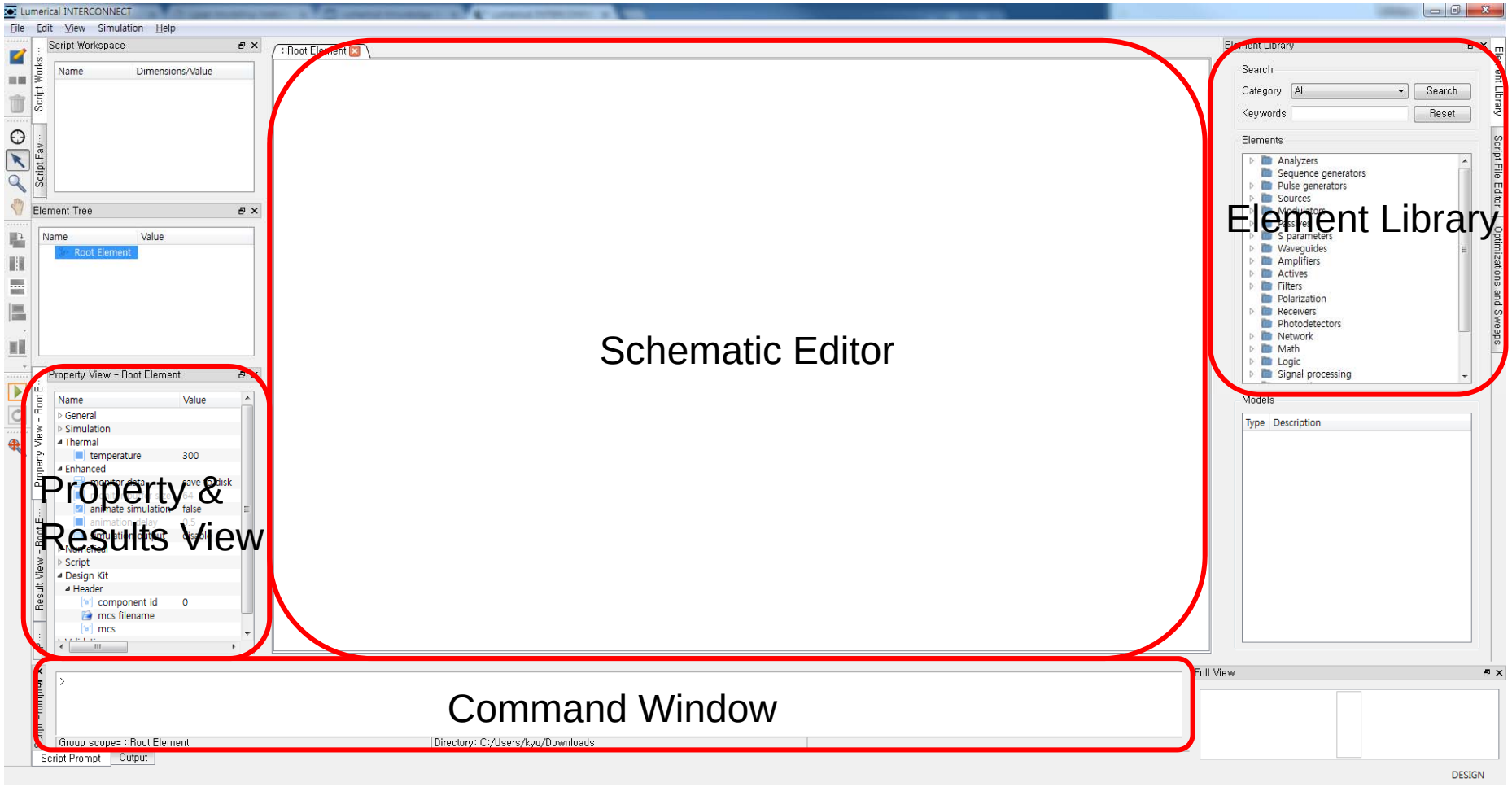
Hierarchical Simulation(INTERCONNECT)



License setup

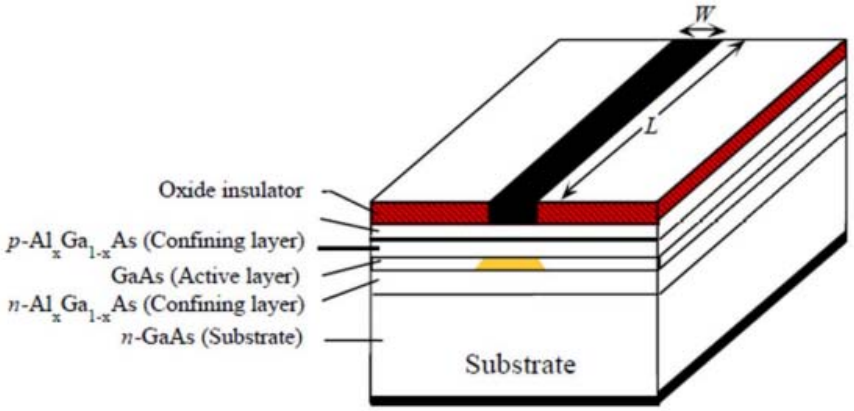


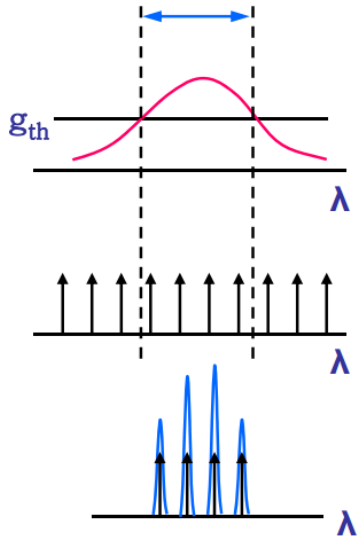
INTERCONNECT Window



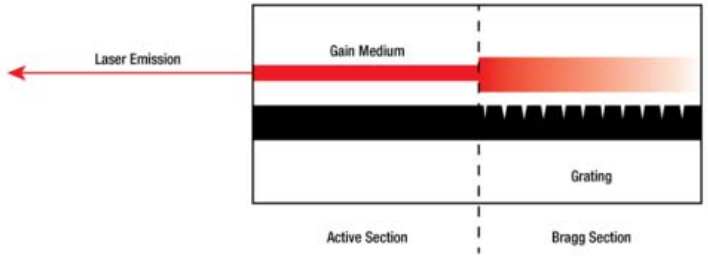
Several Types of LASERs

Fabry-Perot(FP) Laser

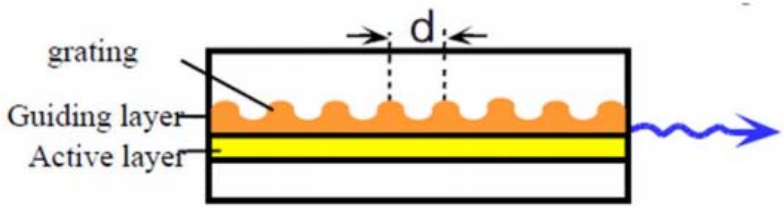




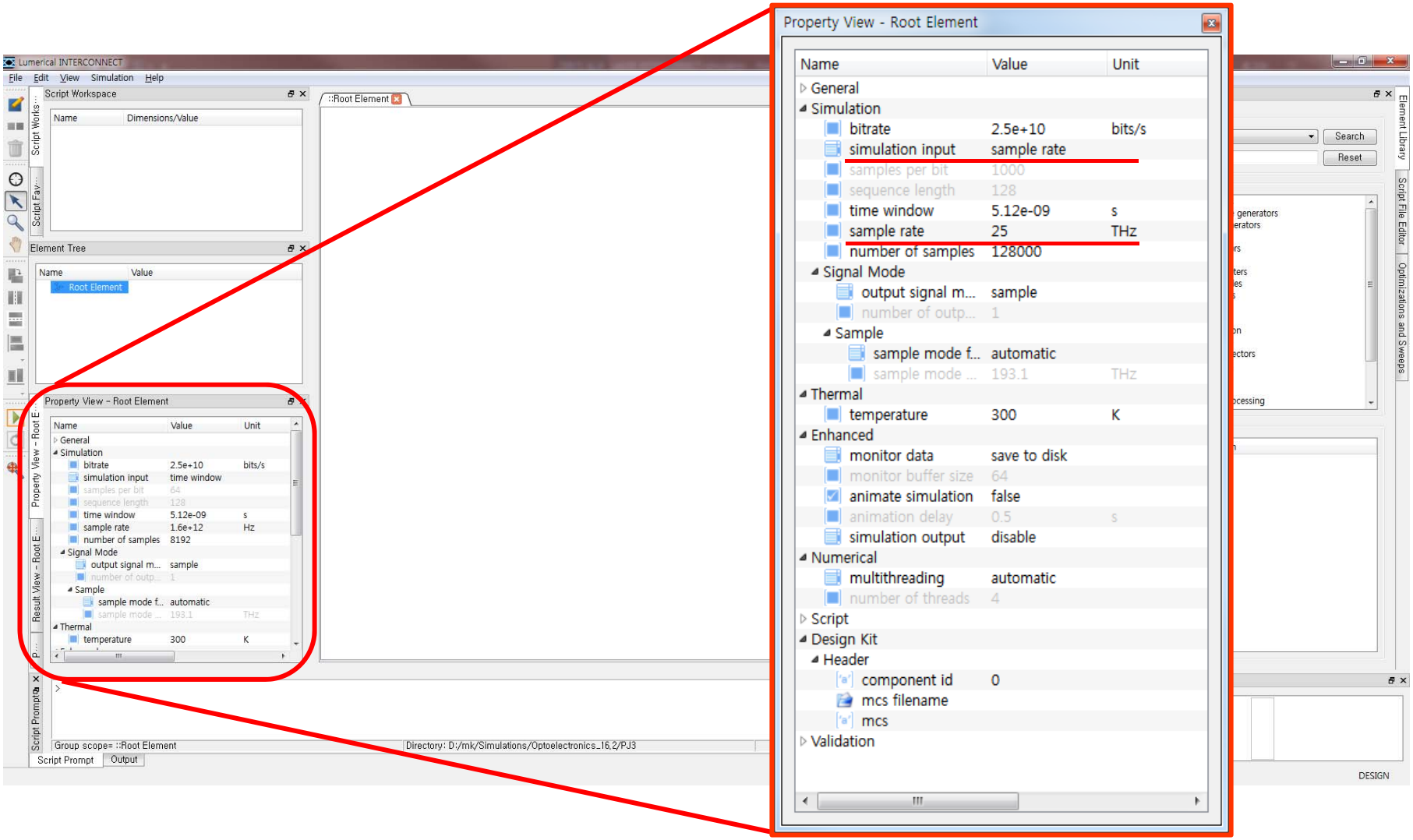
Distributed Bragg Reflector (DBR) Laser



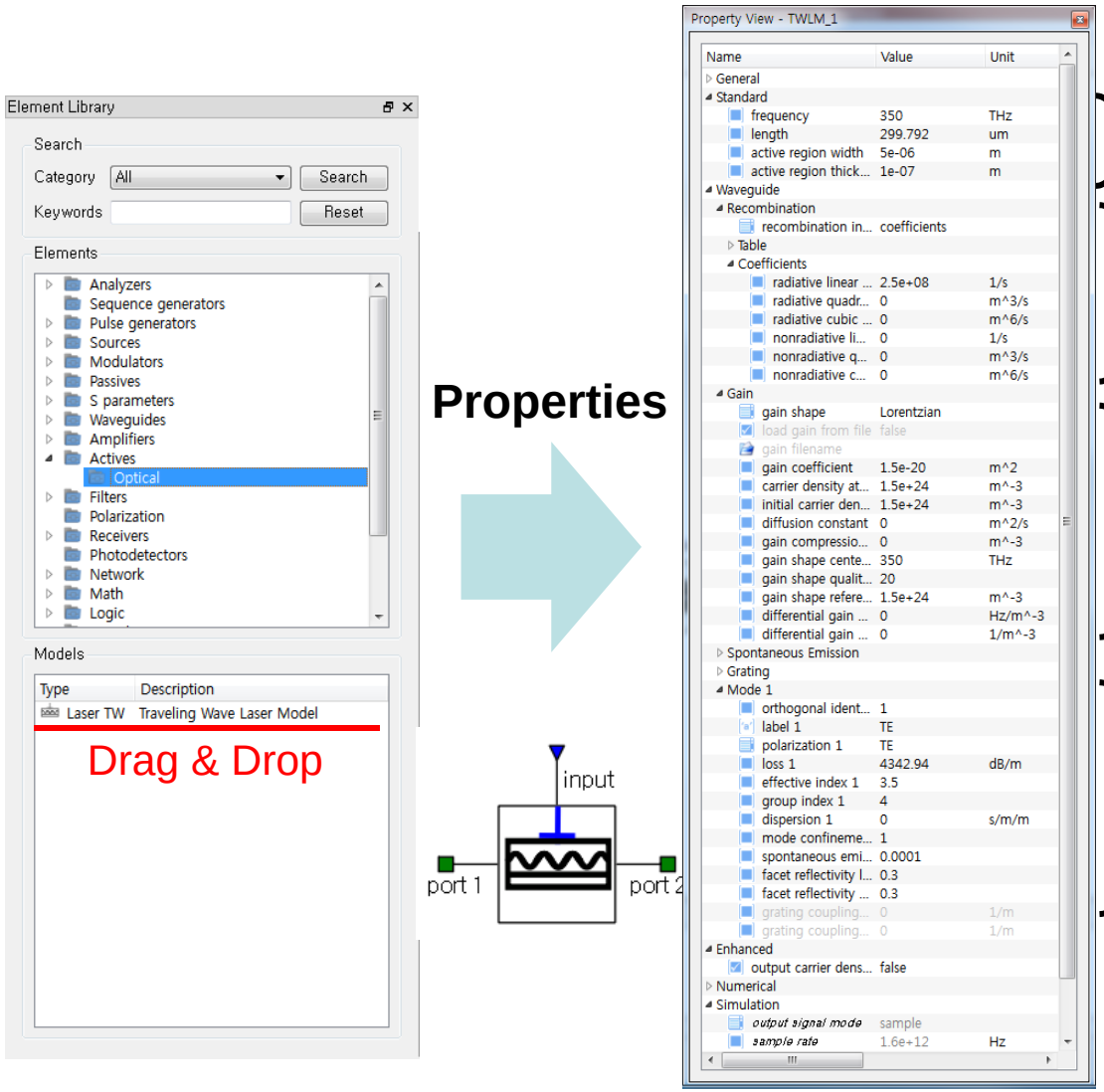
Distributed Feedback (DFB) Laser



Simulation Setup



Gain Medium(TWLM)



Standards
:Frequency, structure of laser

Recombination

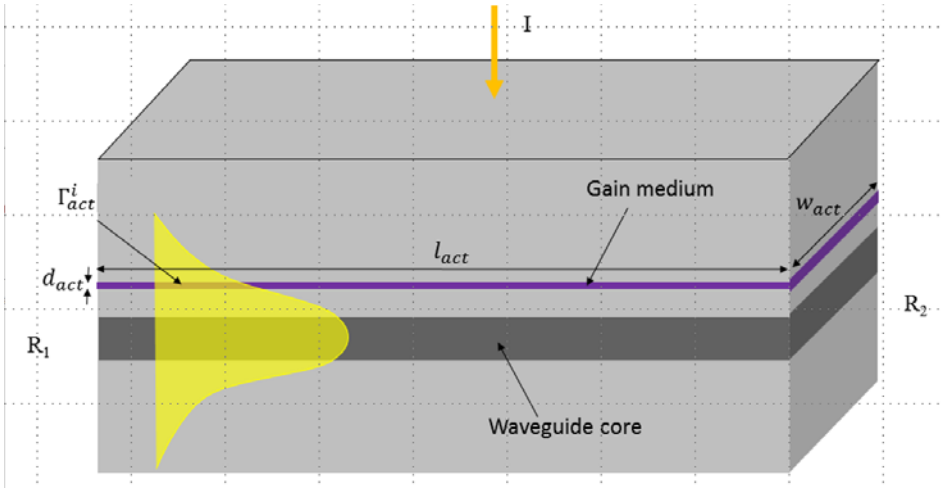
Gain
:Gain curve shape

Mode1
:Loss, n_g, facet reflectivity

Properties of TWLM

✓ **Structure of laser(Standard)**

Standard		
frequency	350	THz
length	299.792	um
active region width	5e-06	m
active region thick...	1e-07	m



✓ **Recombination**

Recombination			
recombination in...	coefficients		
Table			
Coefficients			
radiative linear ...	2.5e+08	A	1/s
radiative quadr...	0	B	m^3/s
radiative cubic ...	0	C	m^6/s
nonradiative li...	0		1/s
nonradiative q...	0		m^3/s
nonradiative c...	0		m^6/s

$$\frac{dN}{dt} = \frac{N}{\tau} \qquad \tau = [A + BN + CN^2]^{-1} \qquad \frac{\Delta N}{\Delta T} = AN + BN^2 + CN^3$$

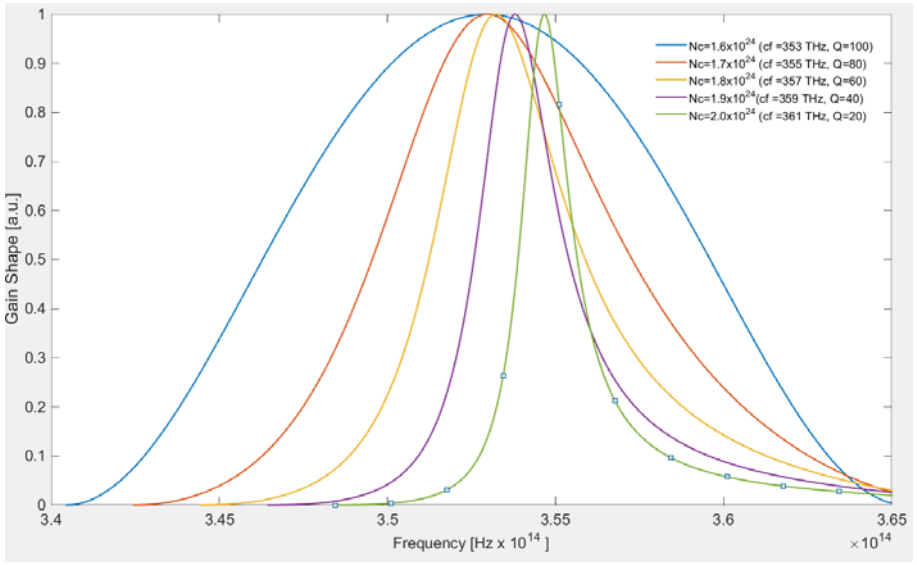
A: monomolecular
B: bimolecular
C: Auger

Properties of TWLM

✓ **Gain shape**

Gain			
gain shape	Lorentzian		
load gain from file	false		
gain filename			
gain coefficient	1.5e-20	a_p	m^2
carrier density at...	1.5e+24	N_{tr}	m^-3
initial carrier den...	1.5e+24		m^-3
diffusion constant	0		m^2/s
gain compressio...	0		m^-3
gain shape cente...	350		THz
gain shape qualit...	20		
gain shape refere...	1.5e+24		m^-3
differential gain ...	0		Hz/m^-3
differential gain ...	0		1/m^-3

$$g(f,N) = g_{peak} L(f_c, Q)$$
$$g_{peak} = a_p(N - N_{tr})$$



✓ **Mode setting**

Mode 1			
orthogonal ident...	1		
label 1	TE		
polarization 1	TE		
loss 1	4342.94		dB/m
effective index 1	3.5		
group index 1	4		
dispersion 1	0		s/m/m
mode confineme...	1	Γ	
spontaneous emi...	0.0001		
facet reflectivity l...	0.3	Reflectivity	
facet reflectivity ...	0.3		
grating coupling...	0		1/m
grating coupling...	0		1/m

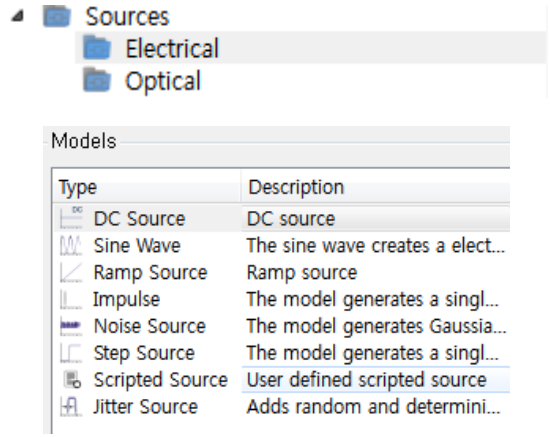
Enhanced		
output carrier dens...	true	

Diagnostic		
run diagnostic	true	Gain spectrum
diagnostic size	1024	

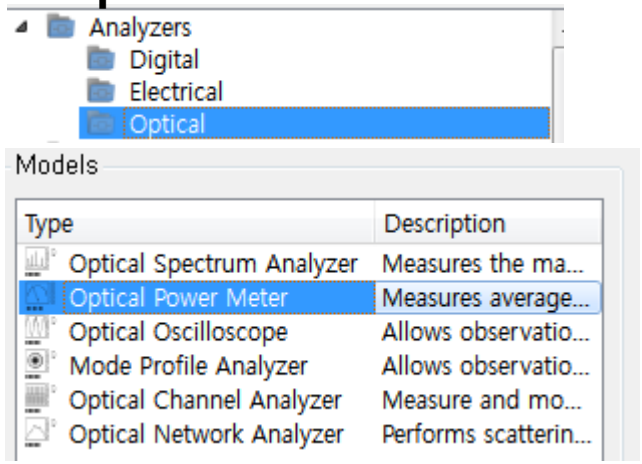
Facet reflectivity can be used for Febry-Perot laser simulation

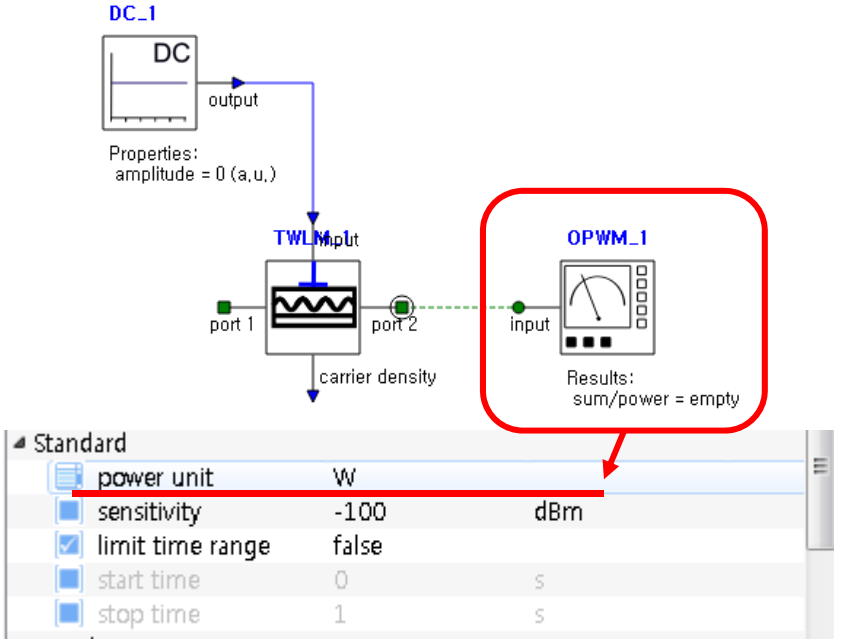
Gain spectrum and LI curve

✓ **DC source**



✓ **Optical power meter**



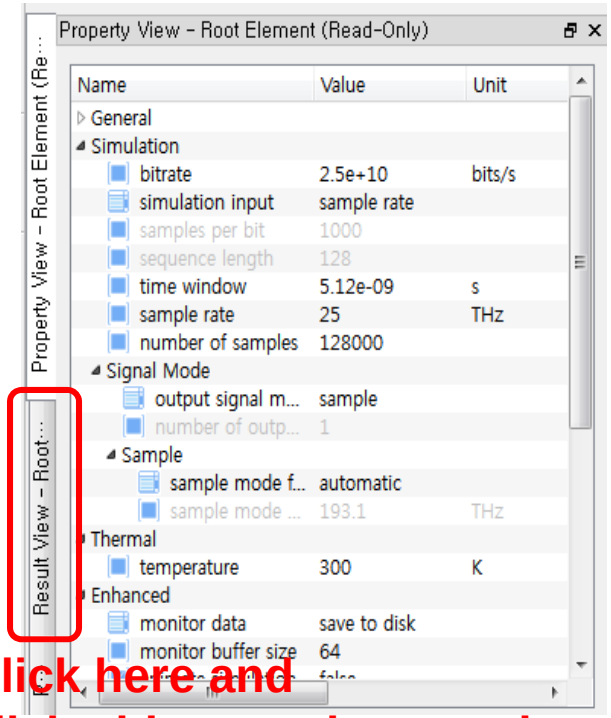


Simulate, and sweep setup!

➔Sweep DC amplitude,
save result of power

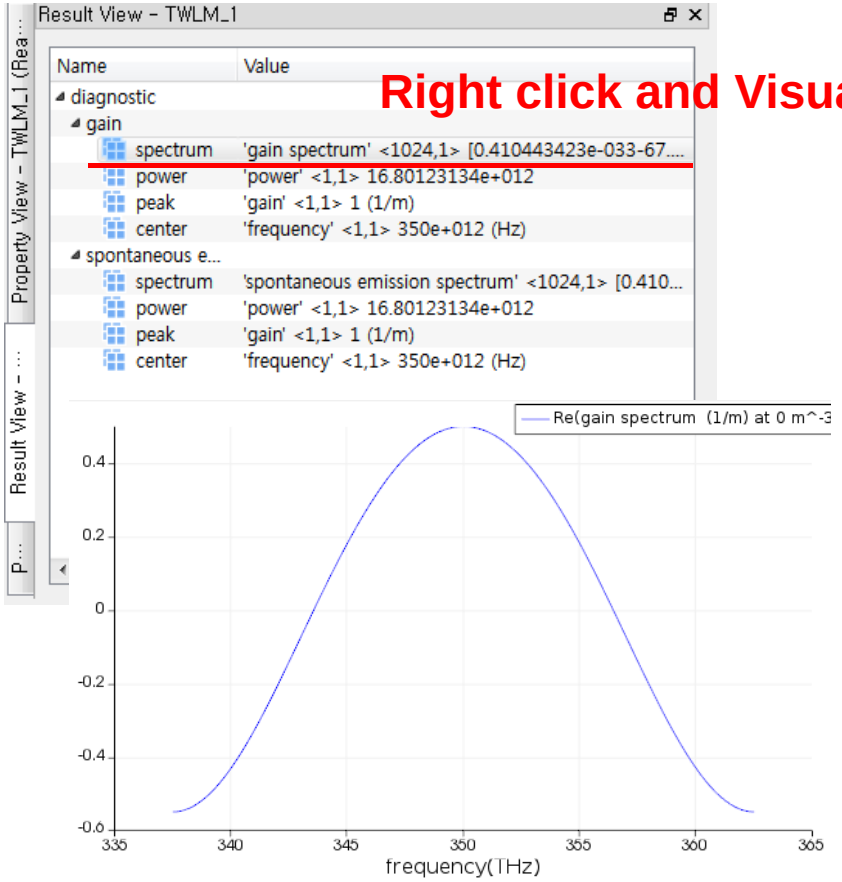
Gain spectrum

Click run



Click here and click object to view result

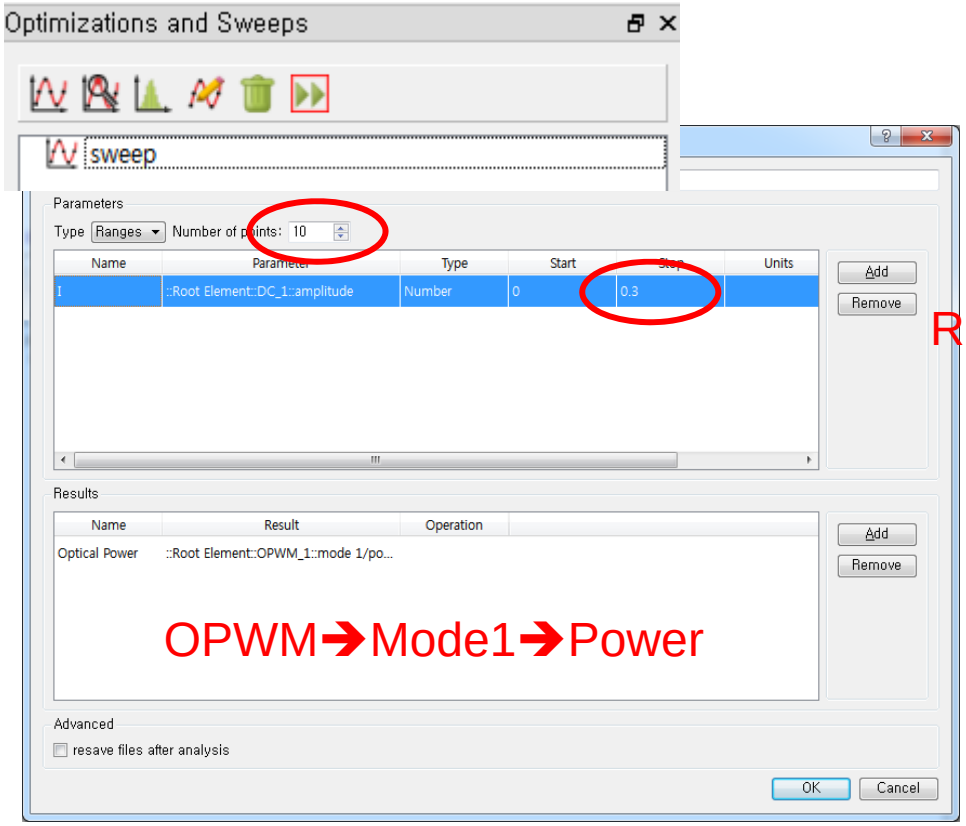
✓ **TWLM gain curve**

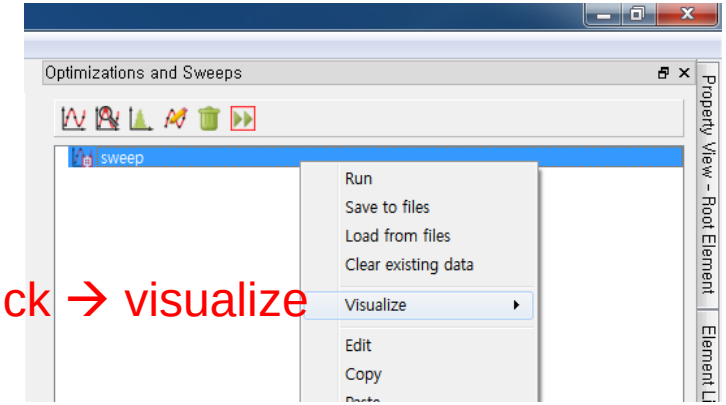


Right click and Visualize

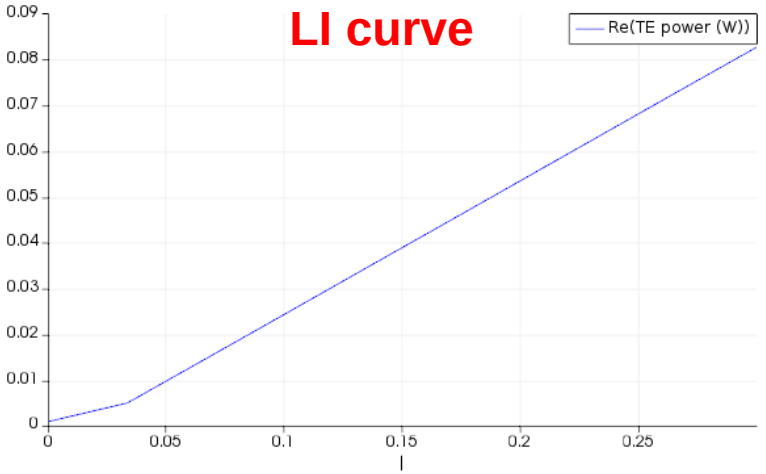
→ FP Laser's gain spectrum

Sweep setup for LI curve





Right click → visualize

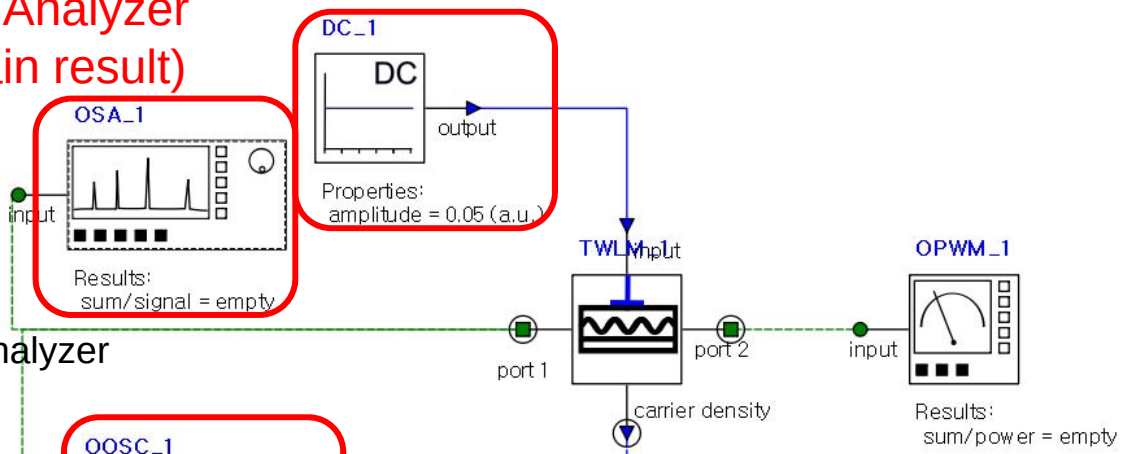


!!! To set output power as sweep output parameter, you have to run simulation first.

Febry-Perot Laser Schematic

Optical Spectrum Analyzer
(Frequency-domain result)

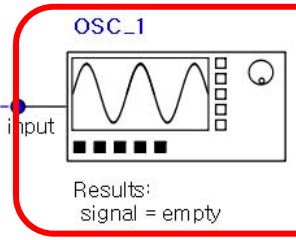
0.05 DC Source



Analyzers ➔ Optical
➔ Optical Spectrum Analyzer

Optical Oscilloscope
(Time-domain result)

Analyzers ➔ Optical ➔ Optical Oscilloscope

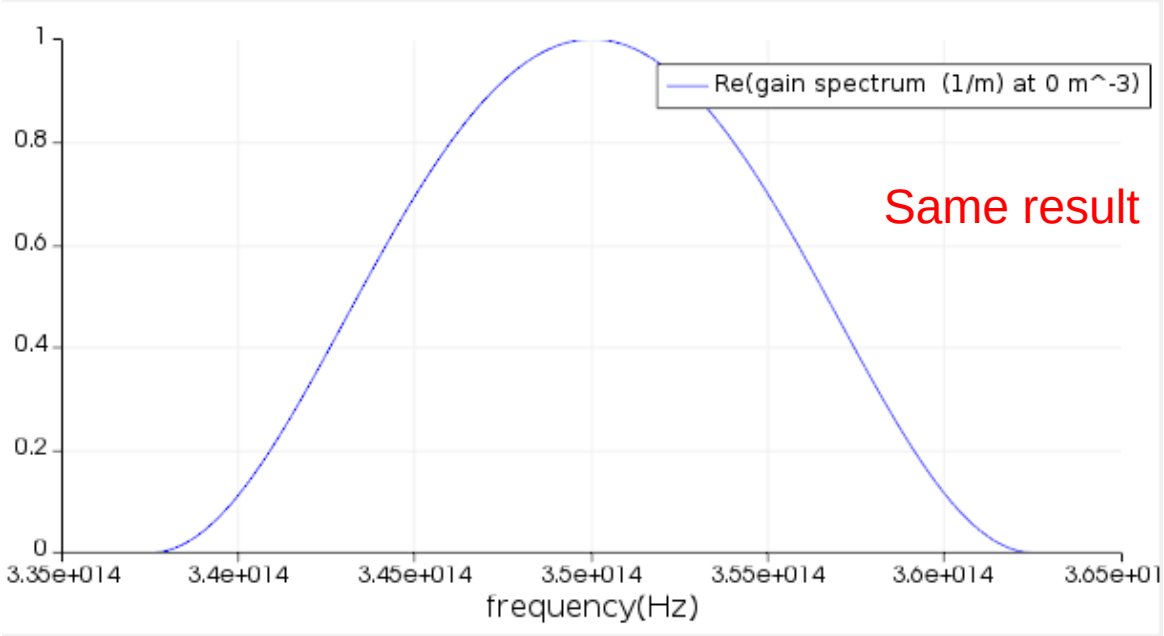


Carrier density
Oscilloscope
(Time-domain result)

Analyzers ➔ Electrical ➔ Oscilloscope

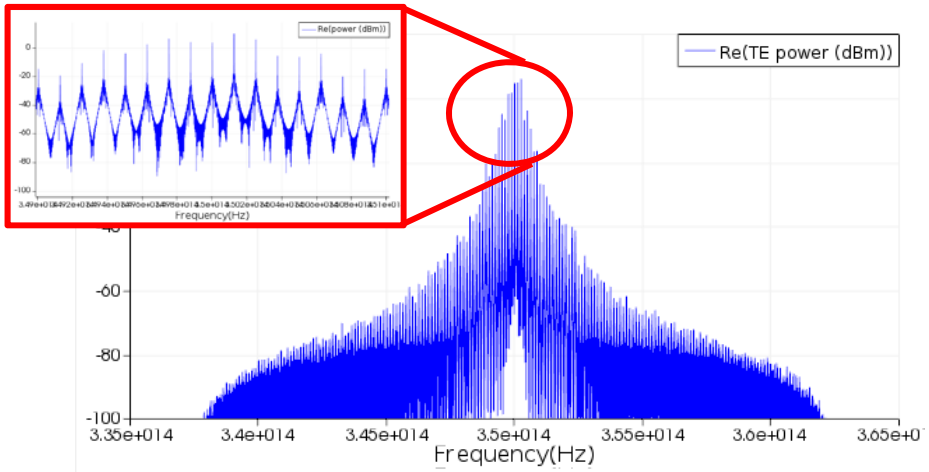
FP Laser Simulation Results

✓ **Gain spectrum**

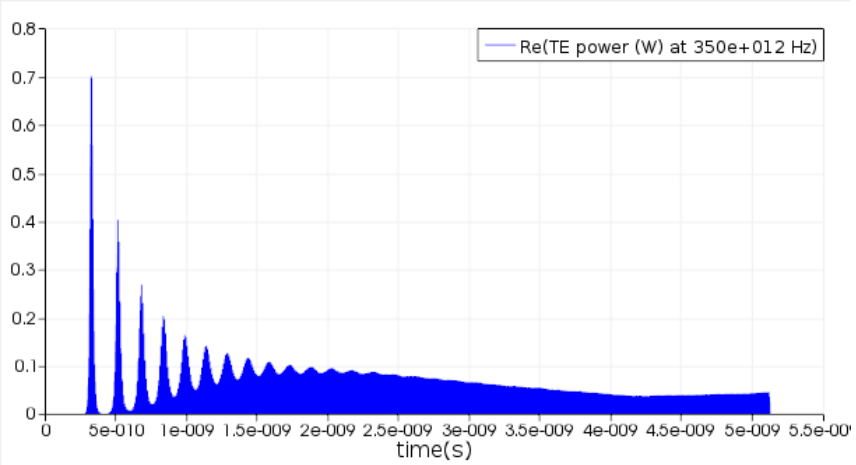


FP Laser Simulation Results

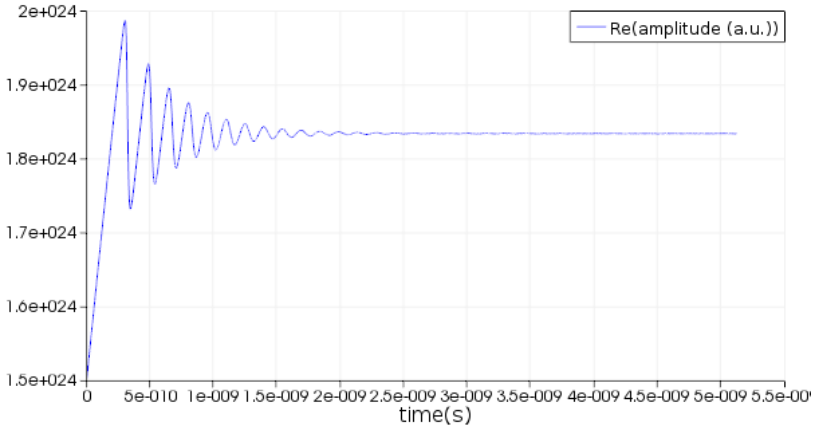
✓ **OSA**



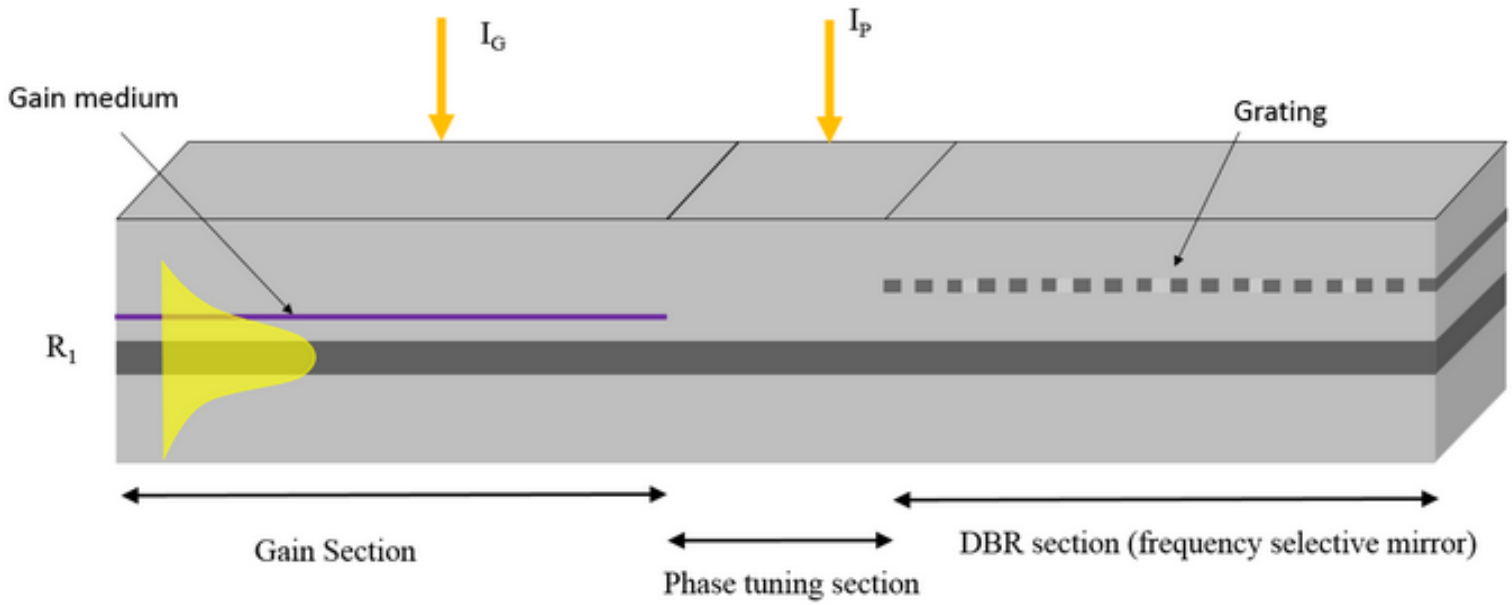
✓ **Optical Oscilloscope(Mode1)**



✓ **Electrical Oscilloscope**

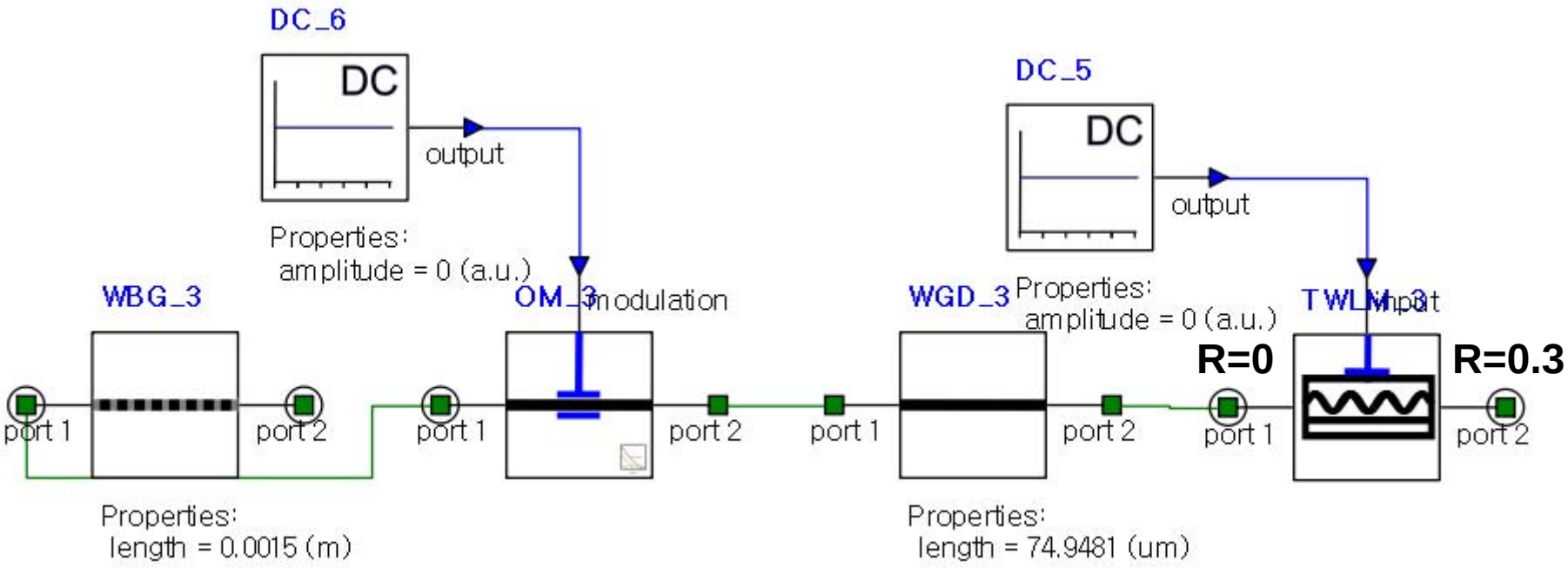


Distributed Bragg Reflector LASER



- ✓ Single-mode by Bragg grating structure
- ✓ Phase tuning region can be controlled with another DC bias

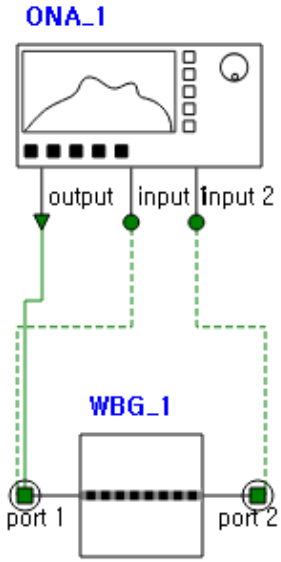
DBR Laser Schematic



✓ Each response analysis is necessary
➔Grating response, FP response(gain medium + waveguide + phase tuning)

Bragg Grating

Optical Network Analyzer
(Gain simulation)



Waveguide ➔ Gratings ➔ Bragg Grating

✓ Optical Network Analyzer setup

Standard		
number of input ports	2	
power	0	dBm
input parameter	center and range	
center frequency	350	THz
frequency range	25	THz
start frequency	337.5	THz
stop frequency	362.5	THz
number of points	10000	
plot kind	frequency	
relative to center	false	
delay	0	s
limit time range	false	
start time	1	s
stop time	1	s

Numerical	
analysis type	impulse response
maximum number of iterati...	1000
stop on convergence	false
multithreading	user defined
number of threads	4

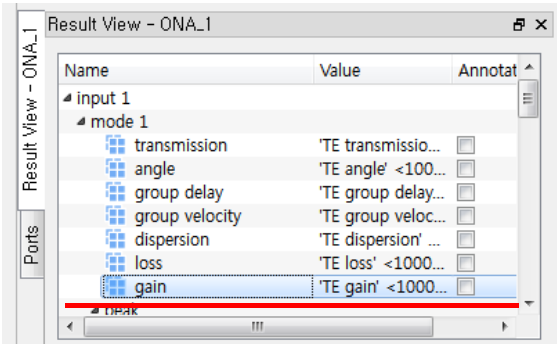
✓ Bragg Grating setup

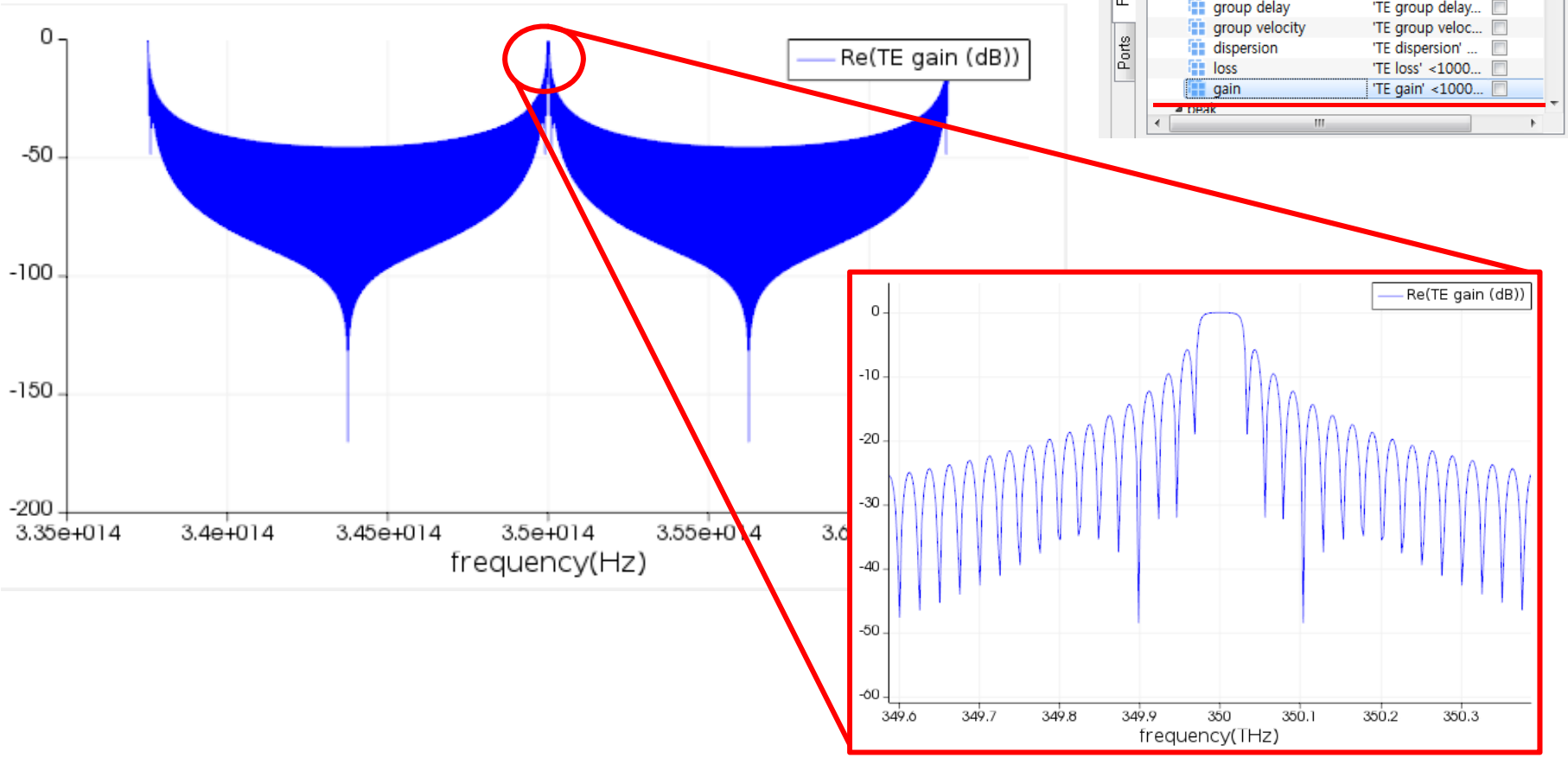
Standard		
configuration	bidirectional	
length	0.0015	m
input parameter	Bragg frequency	
period	5.3e-07	m
frequency	856.55	nm
coupling parameter	effective index ...	
effective index change ac	0.0005	
effective index change dc	0	
grating coupling coefficient	800	
phase shift	0	rad

Mode 1		
orthogonal identifier 1	1	
label 1	TE	
loss 1	0	dB/m
effective index 1	4	
group index 1	4	
facet reflectivity left 1	0	
facet phase left 1	0	rad
facet reflectivity right 1	0	
facet phase right 1	0	rad
Thermal		
effective index temperat...	0	/K
excess loss temperature ...	0	/K

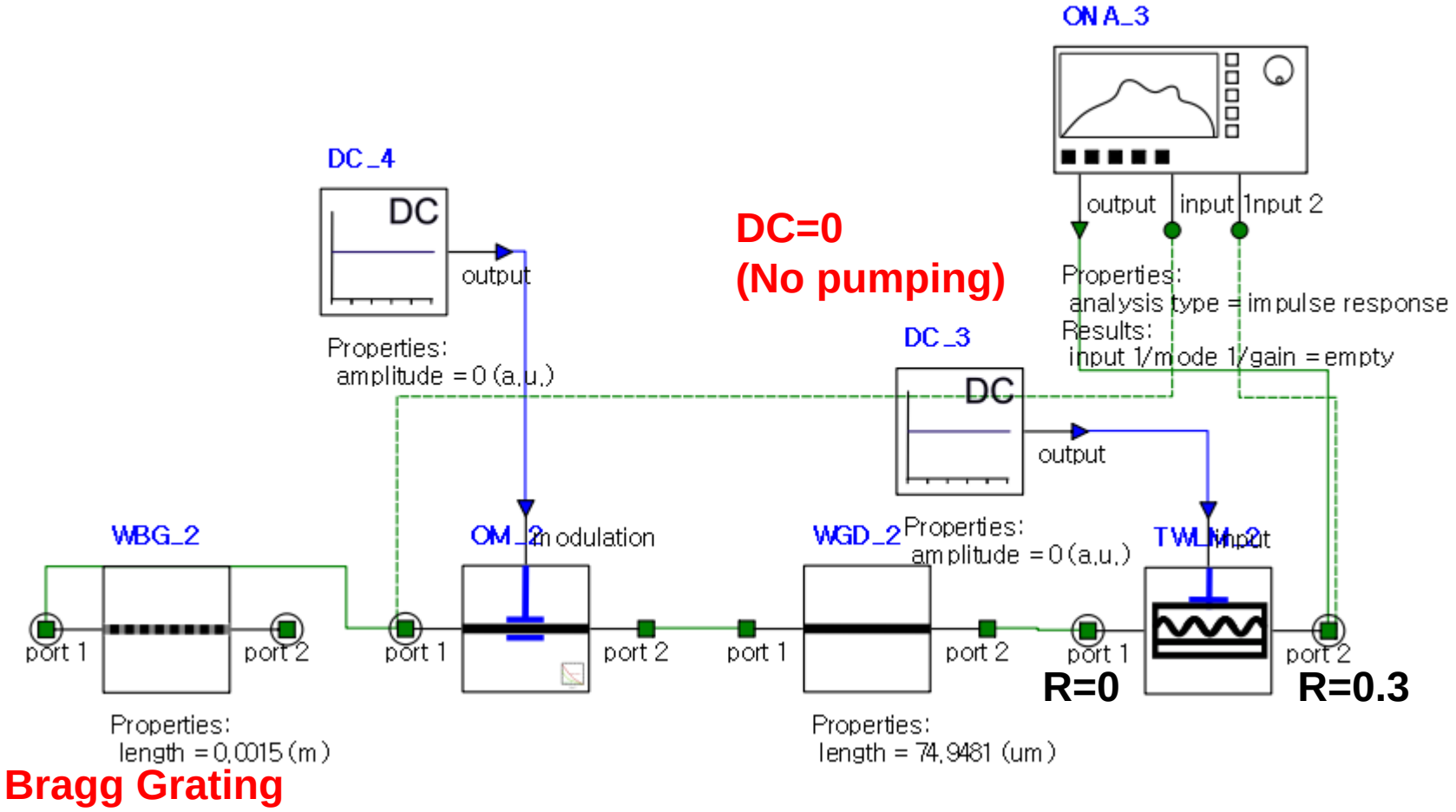
Bragg Grating Simulation Result

Click ONA ➔ Result View ➔ Input1 ➔ Mode1 ➔ plot gain





DBR Laser

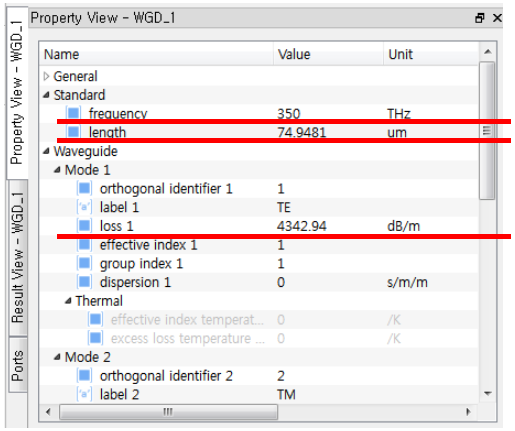


✓ Same models in previous simulations (Bragg grating instead of mirror)

Model Setup

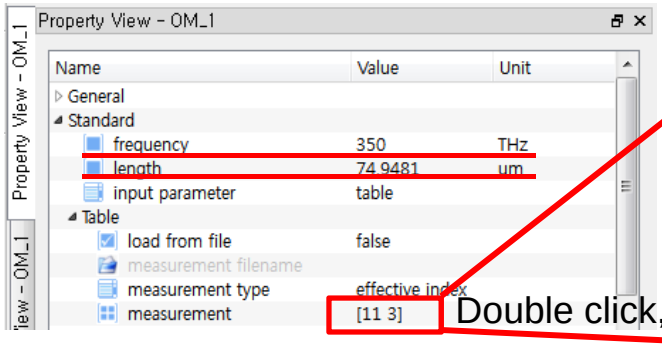
✓ Waveguide setup

Waveguide ➔ Straight waveguide

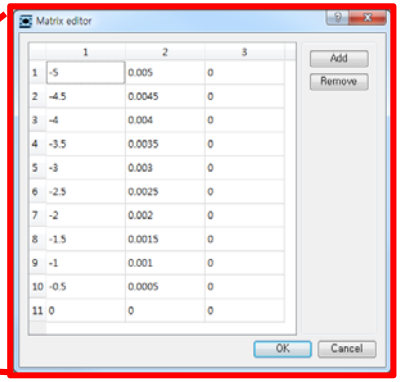


✓ Optical modulator setup

Modulators ➔ Optical ➔ Optical Modulator Measured



Double click, edit

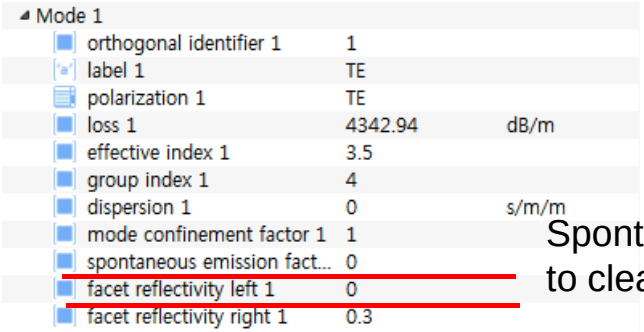


First row: Input source

Second row: n_{eff} changes

✓ TWLM setup

Same as FP simulation, but two changes



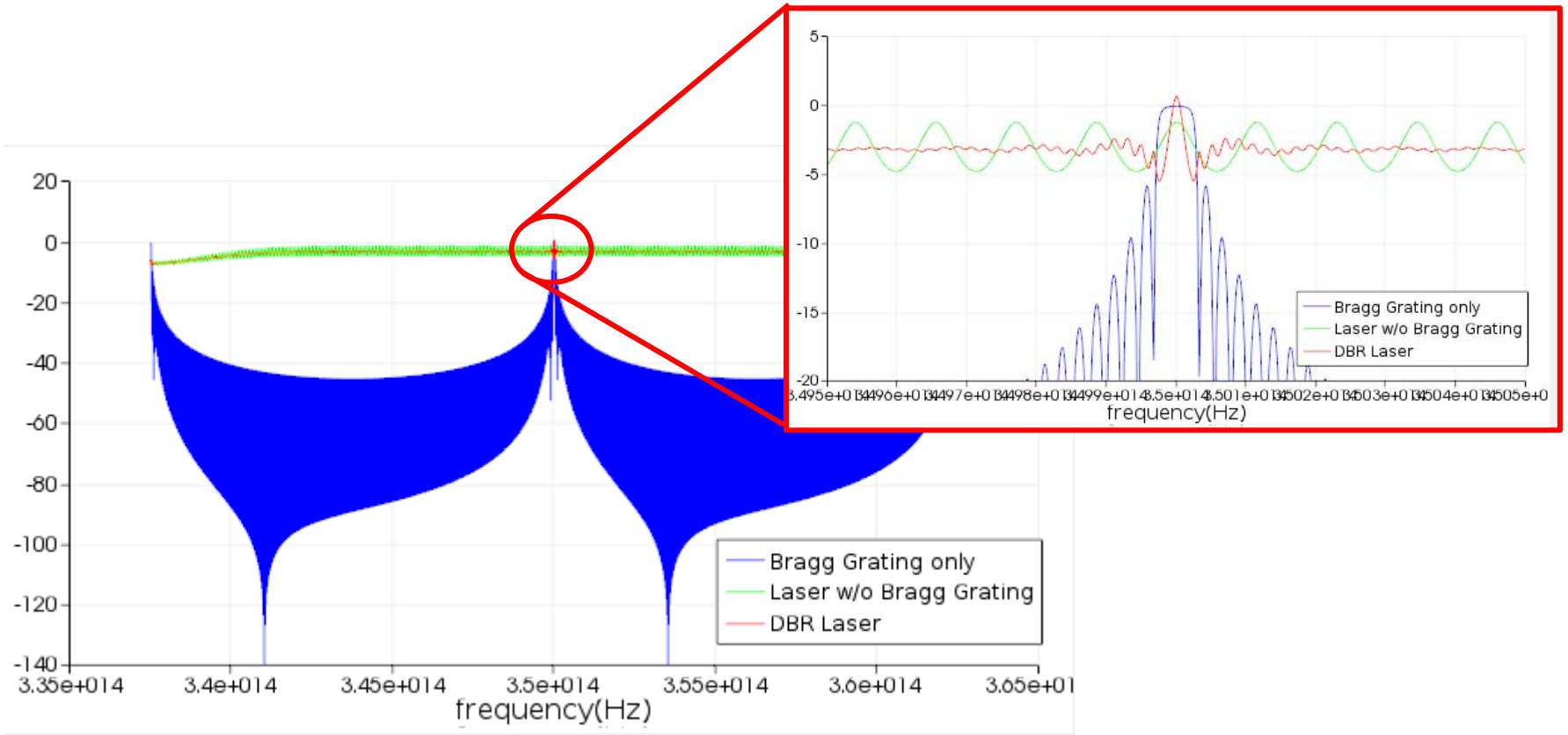
Spontaneous factor should be zero to clearly verify response

✓ ONA setup

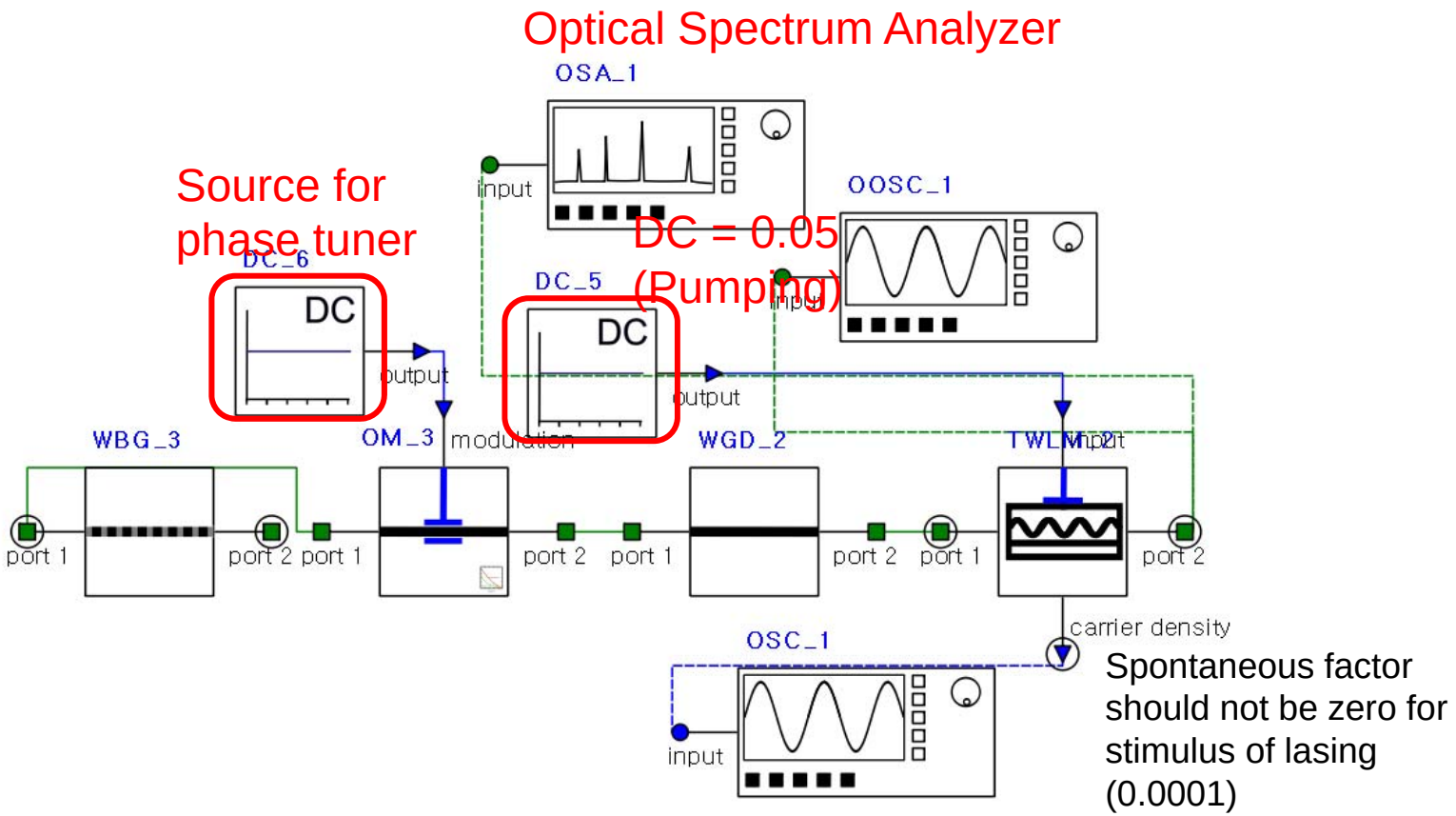
Same as Bragg grating simulation (page 16.)

Simulation Result

Click ONA ➔ Result View ➔ Input1 ➔ Mode1 ➔ plot gain

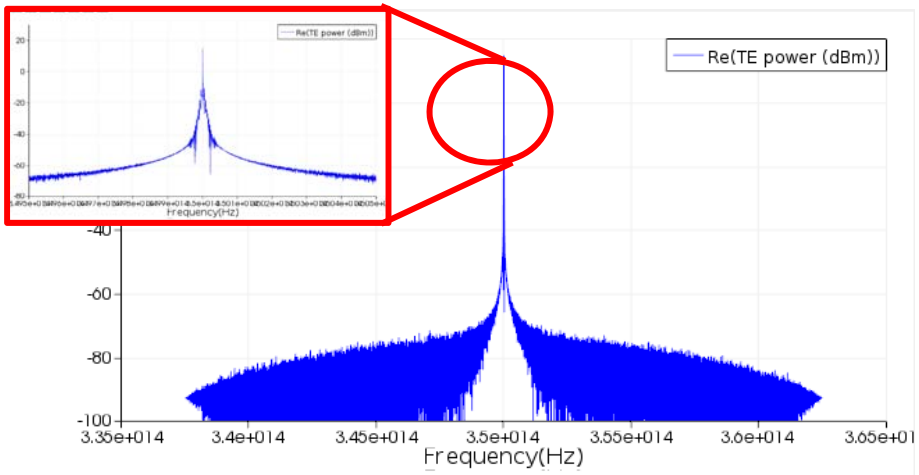


DBR Laser with Pumping Schematic

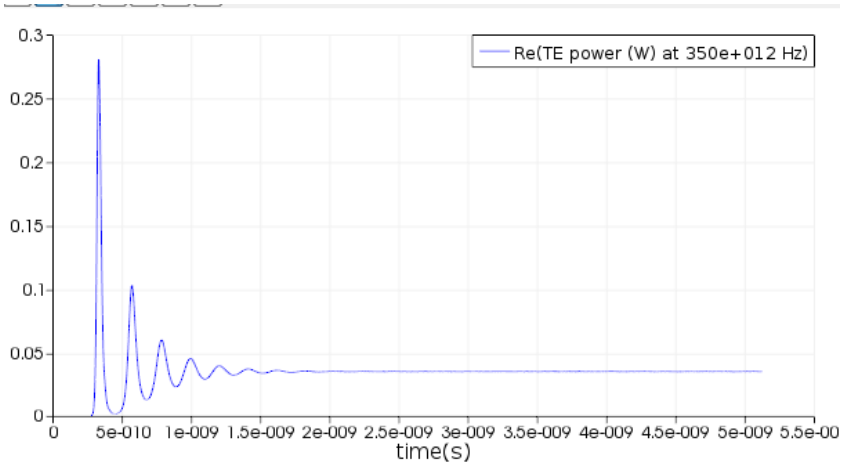


Simulation Result

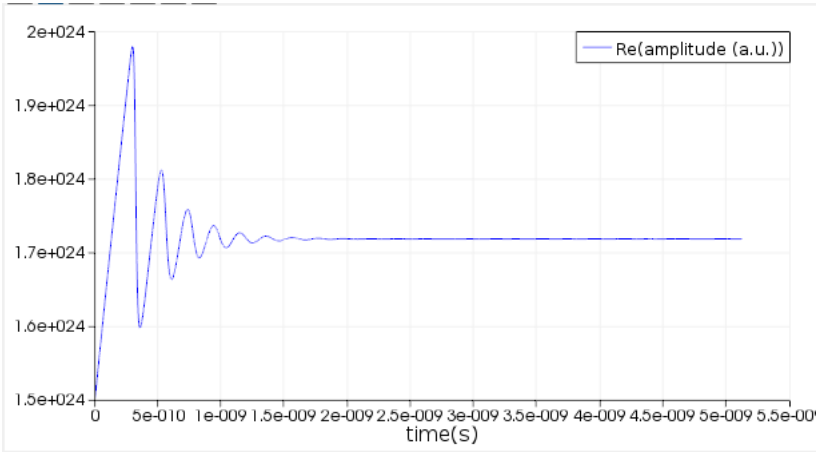
✓ **OSA**



✓ **Optical Oscilloscope(Mode1)**

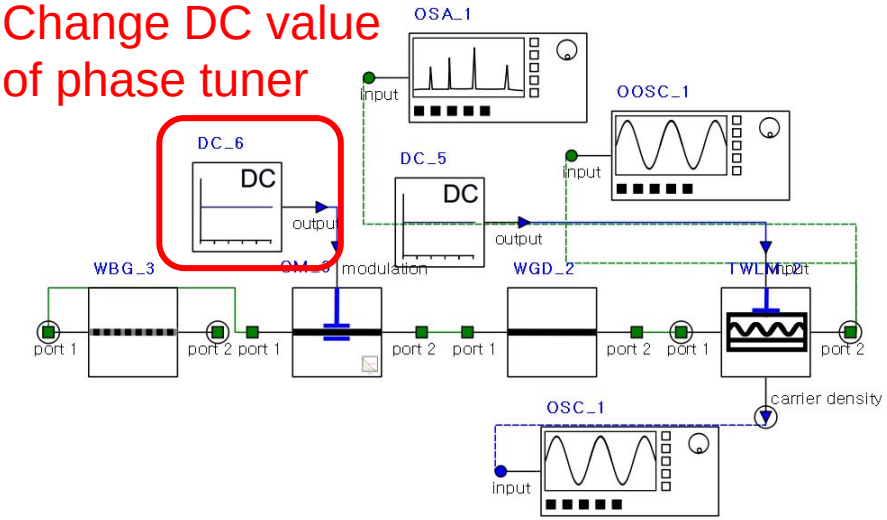


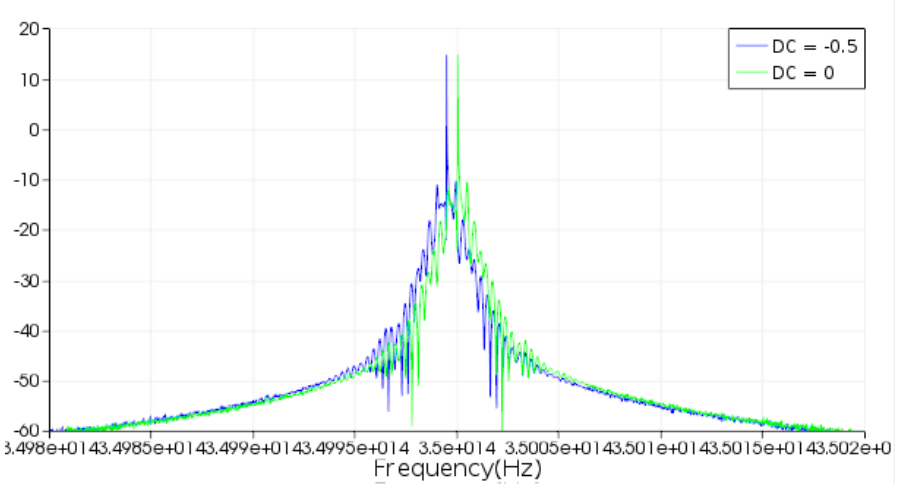
✓ **Electrical Oscilloscope**



Phase Tuned Simulation

Change DC value of phase tuner





✓ Peak frequency can be tuned with phase tuning

Design Exercise 3

a) With Bragg-gating frequency as 349.95 THz (856.672 nm), simulate three different gain response simulation without phase tuning. Also, plot the optical spectrum with optical pumping. Compare & analyze the result with the simulation results obtained in the class.

-Bragg-grating, FP, DBR simulation

b) With phase tuning, find out DC source value for highest output power at 349.95 THz (856.672 nm). Explain how to get the value. Also, analyze the simulation results with theoretical background.

Due date: 22 Dec. PM 6:00 @ B629