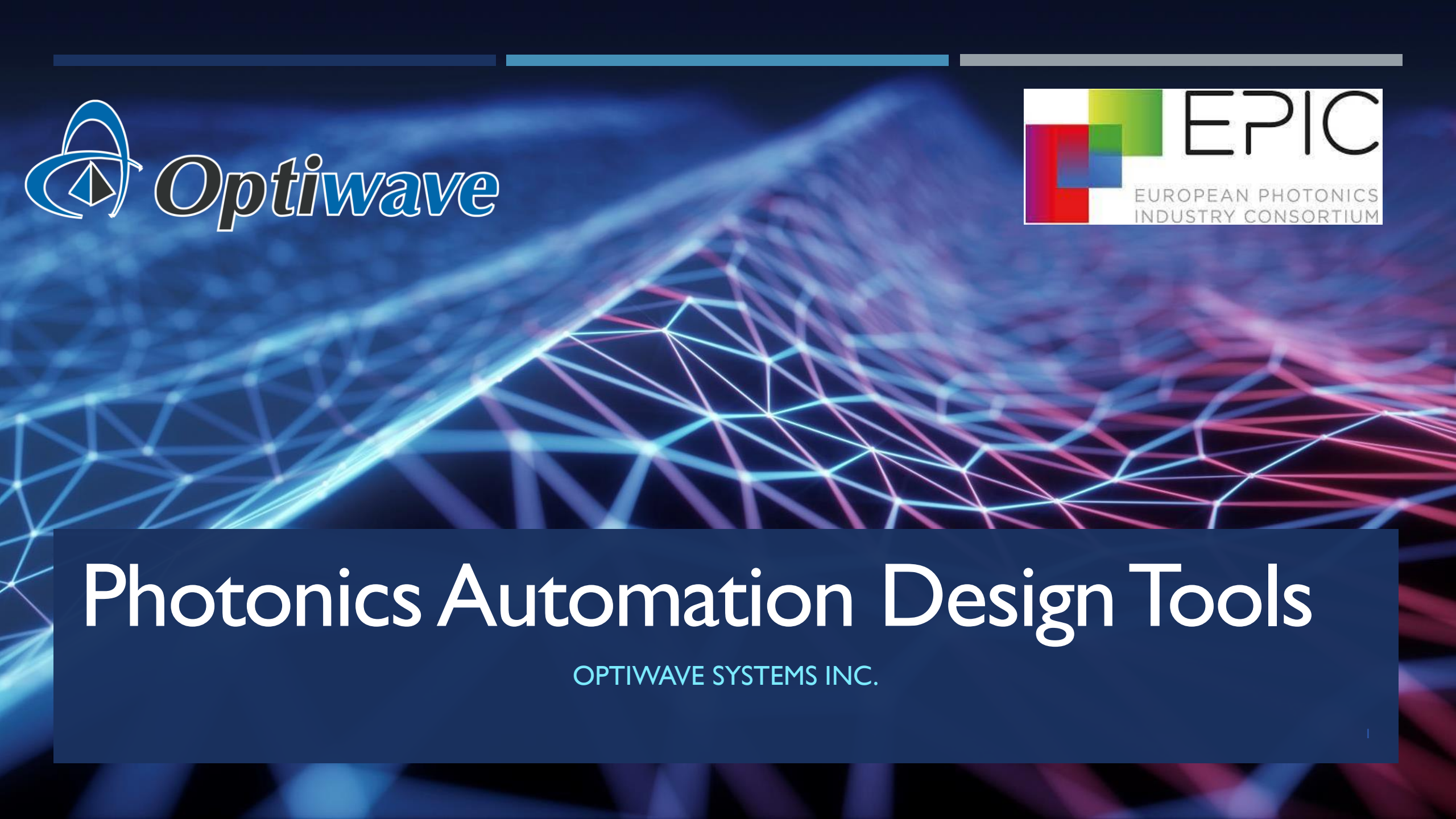
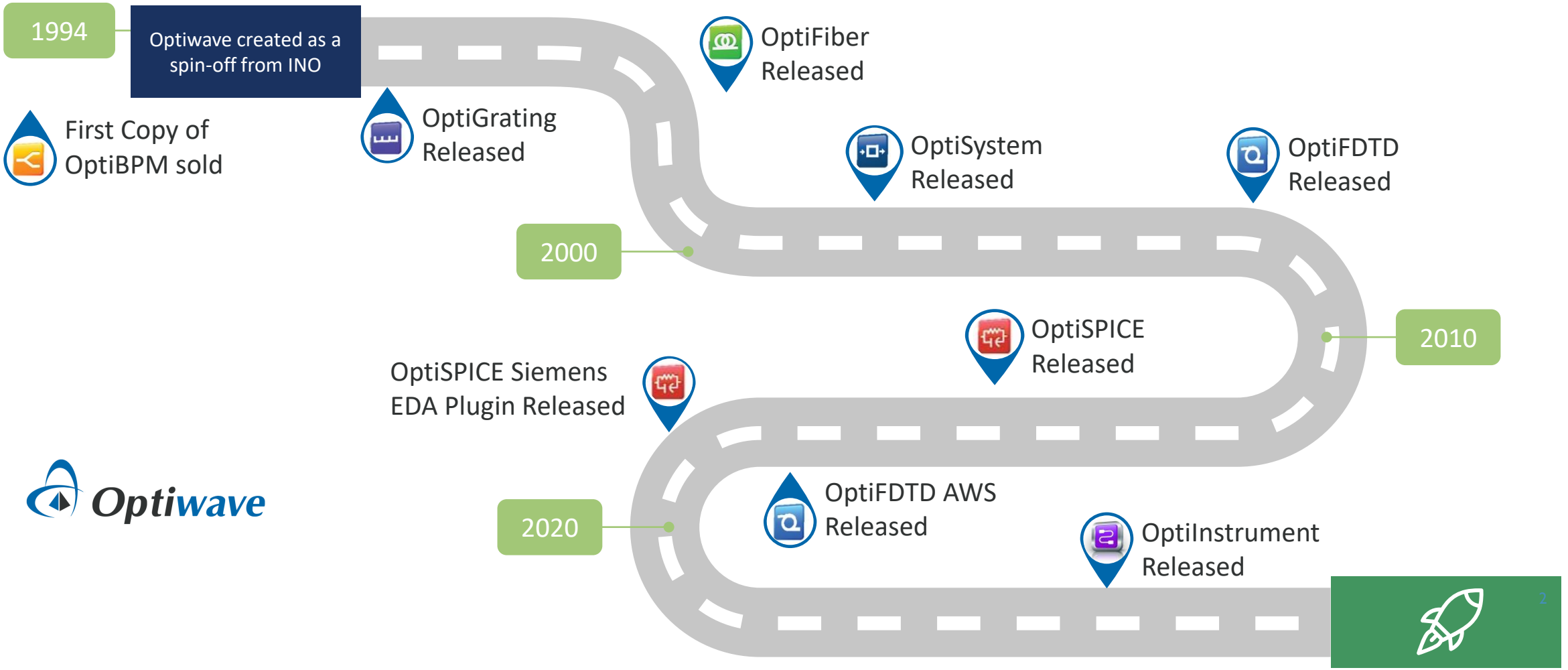


Photonics Automation Design Tools

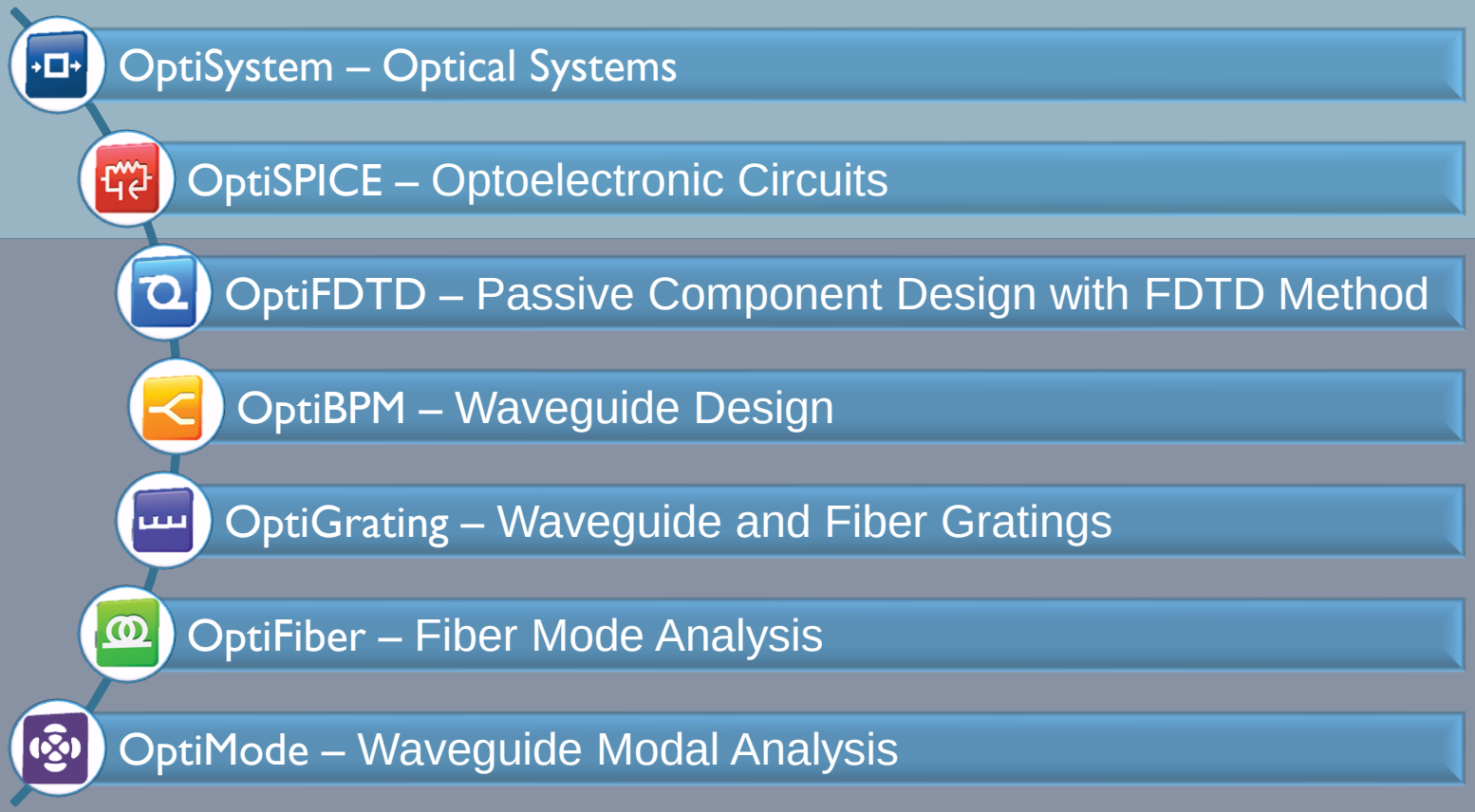
OPTIWAVE SYSTEMS INC.

OPTIWAVE TIMELINE



Optiwave

PHOTONICS AUTOMATION DESIGN TOOLS



SYSTEM LEVEL

COMPONENT LEVEL

COMPANY OVERVIEW

29	7,000+	3,000,000+
Years in Business	Paid Accounts	Evaluation Downloads
80+	15,000+	12,000+
Countries	Paid Users	Citations

OUR KEY CUSTOMERS

Optiwave
DESIGN SOFTWARE

OptiSystem & OptiInstrument Software

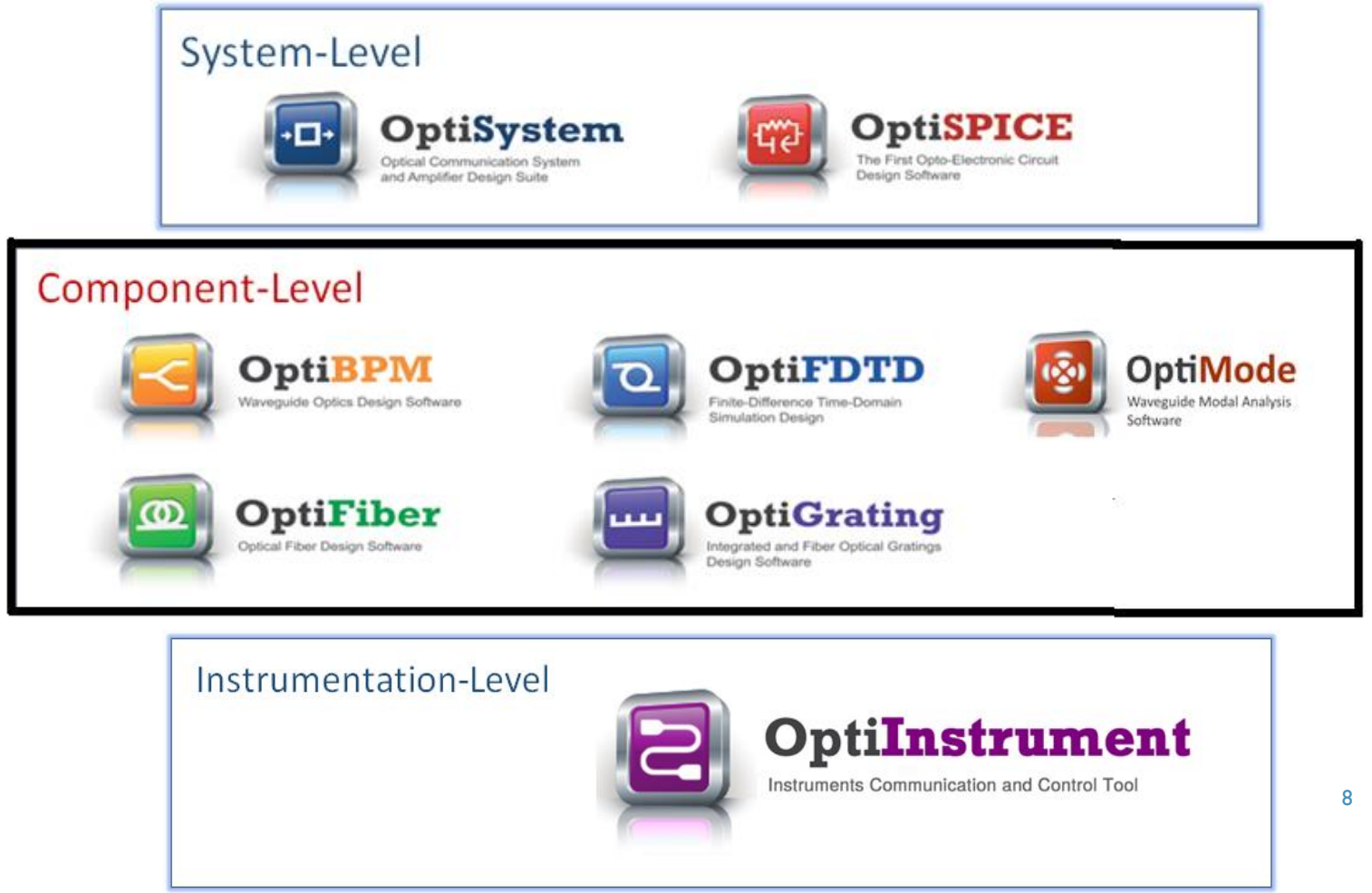
Ahmad Atieh, Ph.D.
VP – Optical Systems

GENERAL INFORMATION

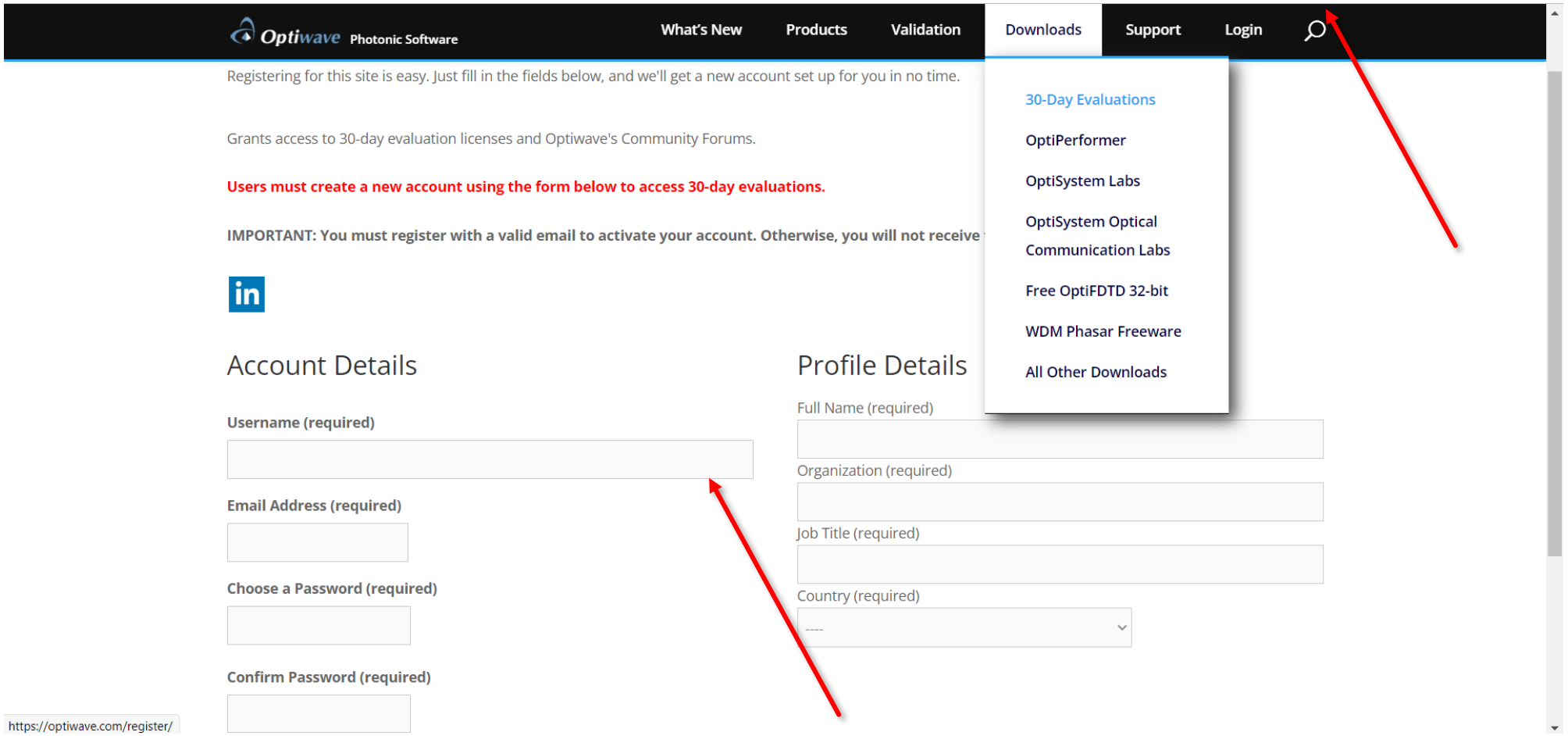
- Optiwave develops innovative software tools for designing, simulating, and optimizing components, links, systems and networks
- Optiwave's software offers users a distinct competitive advantage through
  - shortening product time introduction to the market
  - improving product quality
  - enhancing productivity and cost-effectiveness

PRODUCT LINE

Optiwave's software has been licensed to more than 1000 industry-leading corporations, universities, research and governmental institutions in over than 80 countries worldwide.



OPTIWAVE SOFTWARE DOWNLOAD



C:\Program Files\Optiwave Software\

OptiSystem Components – I

Light Sources (CW, LED, VCSEL, DFB, FP, White Light Source, solar source)

Optical Modulators (MZM: Single/Dual Drive and Single/Dual Port MZM, EAM, PM, AM, FM)

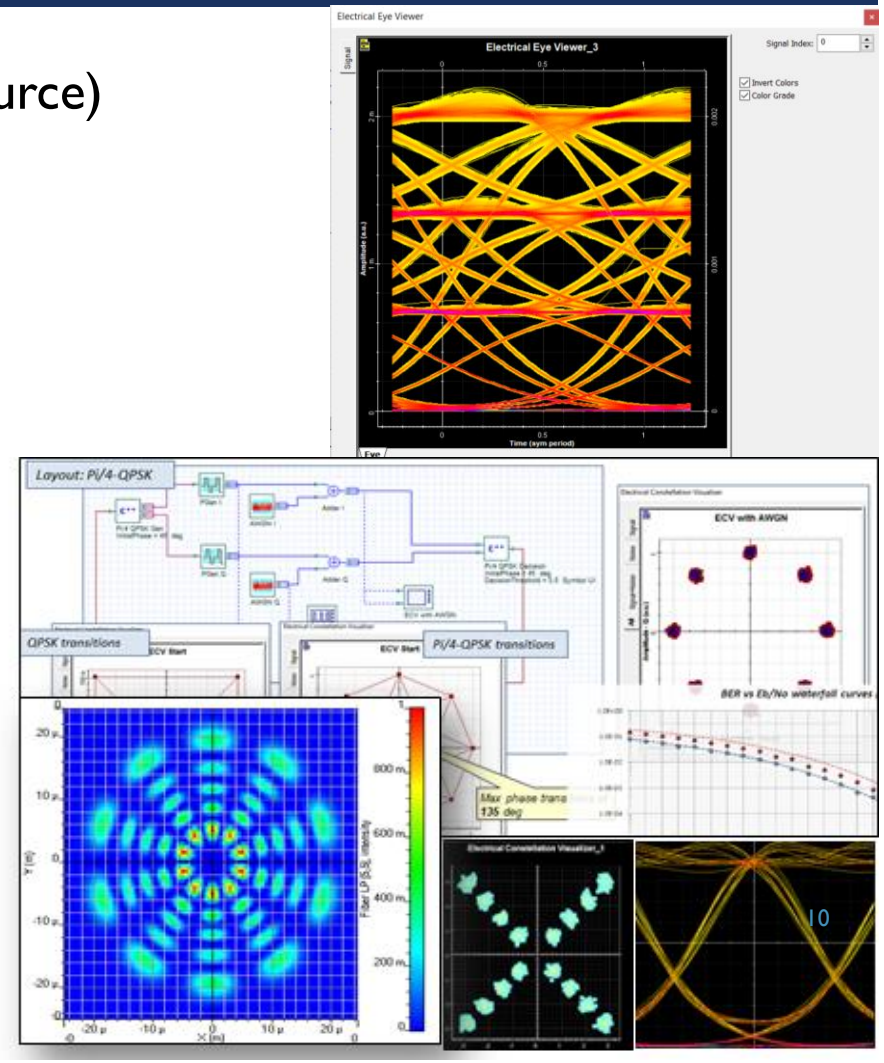
Bit Sequences (PRBS, User Defined, Compliance Test Patterns)

Optical Fiber (SMF, MMF, MCF, PCF)

Electrical Modulators (OFDM, Quadrature Modulator)

Modulation Formats (RZ, NRZ, CSRZ, DB, DPSK, mPSK, mQAM, PAMx, PPM, PAS)

Opto-Electronic Circuits (Ring Resonators, Laser Drivers, Switches, Optical Interconnects)



OptiSystem Components – II

Signal Processing (DSP, MLSE Equalizer, Electronic Equalizer [FFE, DFE, AE], Viterbi Phase Recovery, Data Recovery, Clock Recovery, 3R Regenerator)

FEC and Bit Mapping (Reed-Solomon, LDPC, 4B/5B, 8B/10B, 4B/3T)

Detectors (pin, APD)

Over 580 Components

Optical Amplifiers (ER/Yb/Tm/Pr/Ho, SOA, Raman, GFF Optimization, WG ER/Yb)

Electrical Amplifiers (Transimpedance, Limiting, AGC)

Passive Modules (Couplers, MUX/DEMUX, AWG, Switches, Attenuator, Circulator, etc..)

Multimode Applications (Fiber, amplifier, Mode Generator, Passives, Spatial Visualizers)

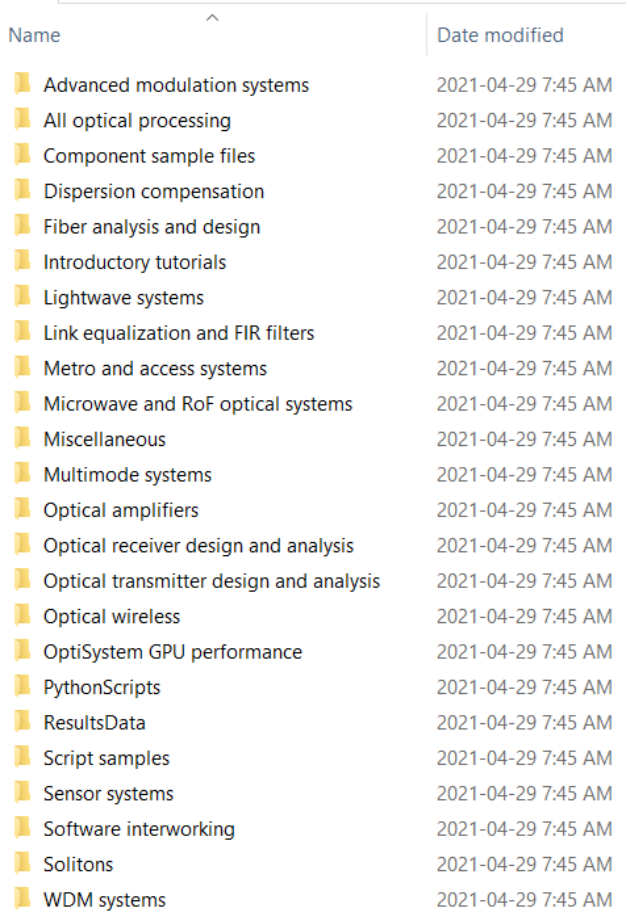
Optical Channel (Fiber, LiFi, Satellite, FSO, VLC, underwater FSO)

Visualizers (Optical, Electrical, Binary, M-ary, BERT, Lightwave Analyzer)

Unidirectional & Bidirectional and Single & Dual Polarization

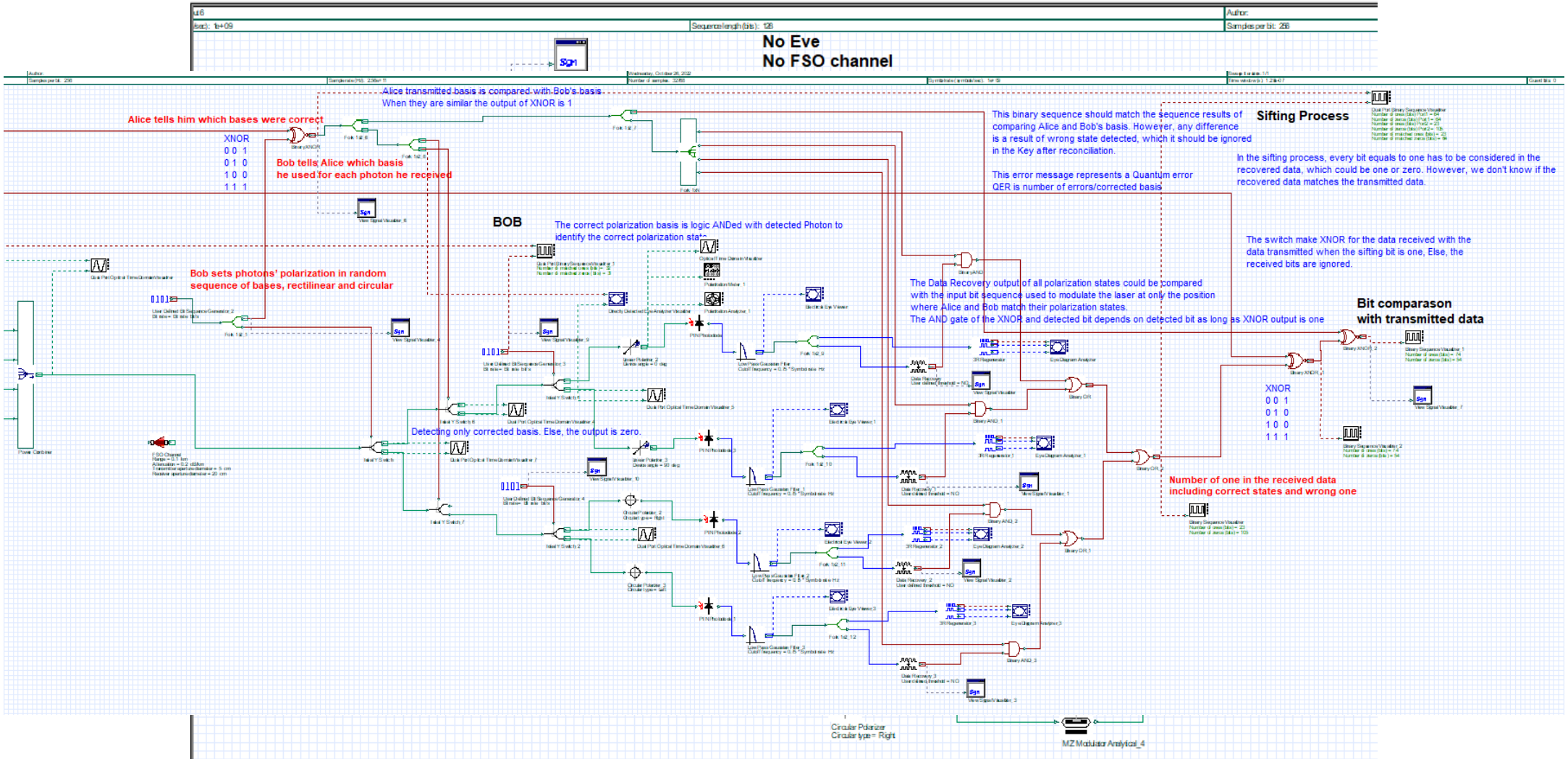
OptiSystem Software Applications & Example Library

- Advanced Modulation (mQAM, PAMx, mPSK, PAS)
- New Radio front-haul
- Optical Amplifiers – Optimization
- Microwave Photonics
- Sensors
  - OTDR & Phi-OTDR
  - FBG
  - PCF for Biosensing
- Optical Wireless Communication
  - LiFi ·VLC
  - Satellite ·FSO and under water FSO
- Spatial Division Multiplexing
  - Few Modes MMF
  - SM and MM MCF

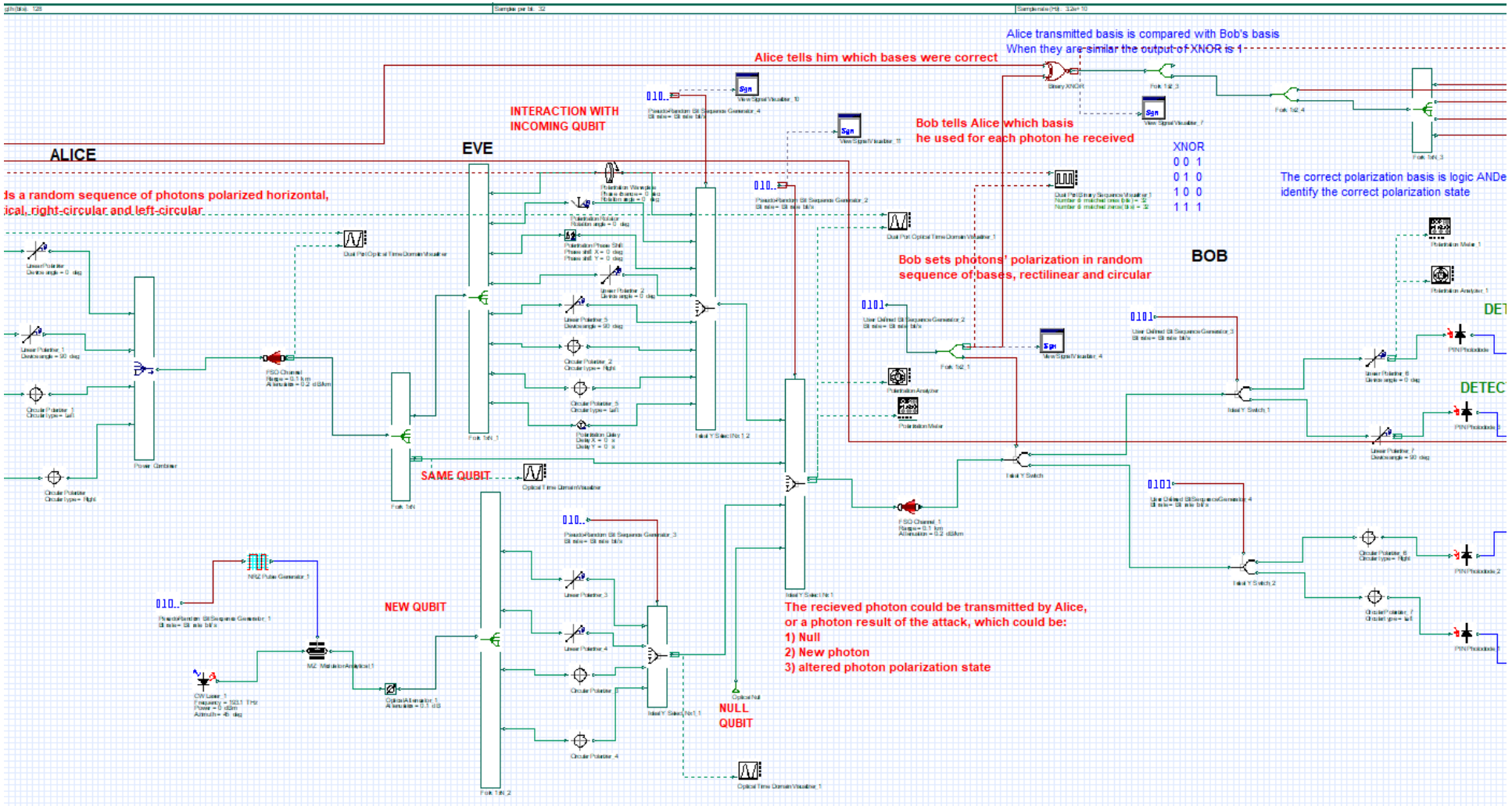


Over 930 .osd files in 241 folders

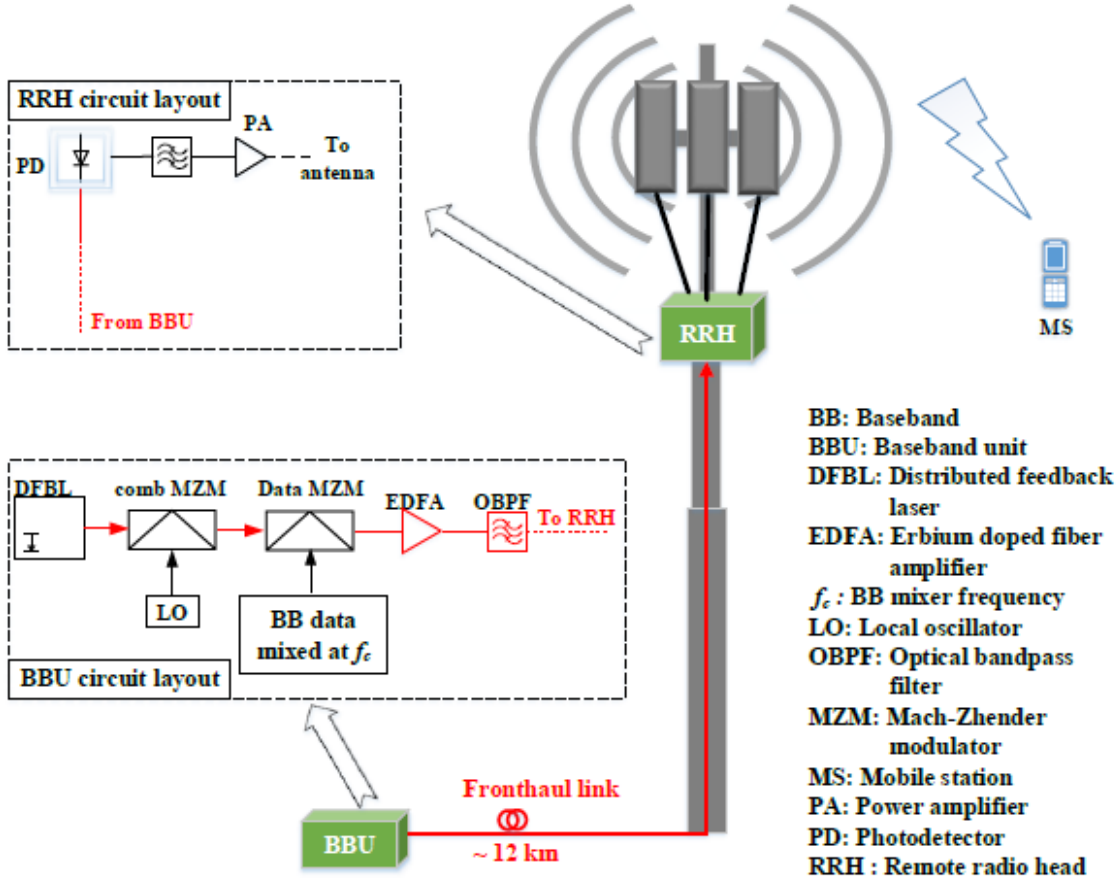
GENERAL BB84 QKD SETUP3



EVE ATTACK SETUP

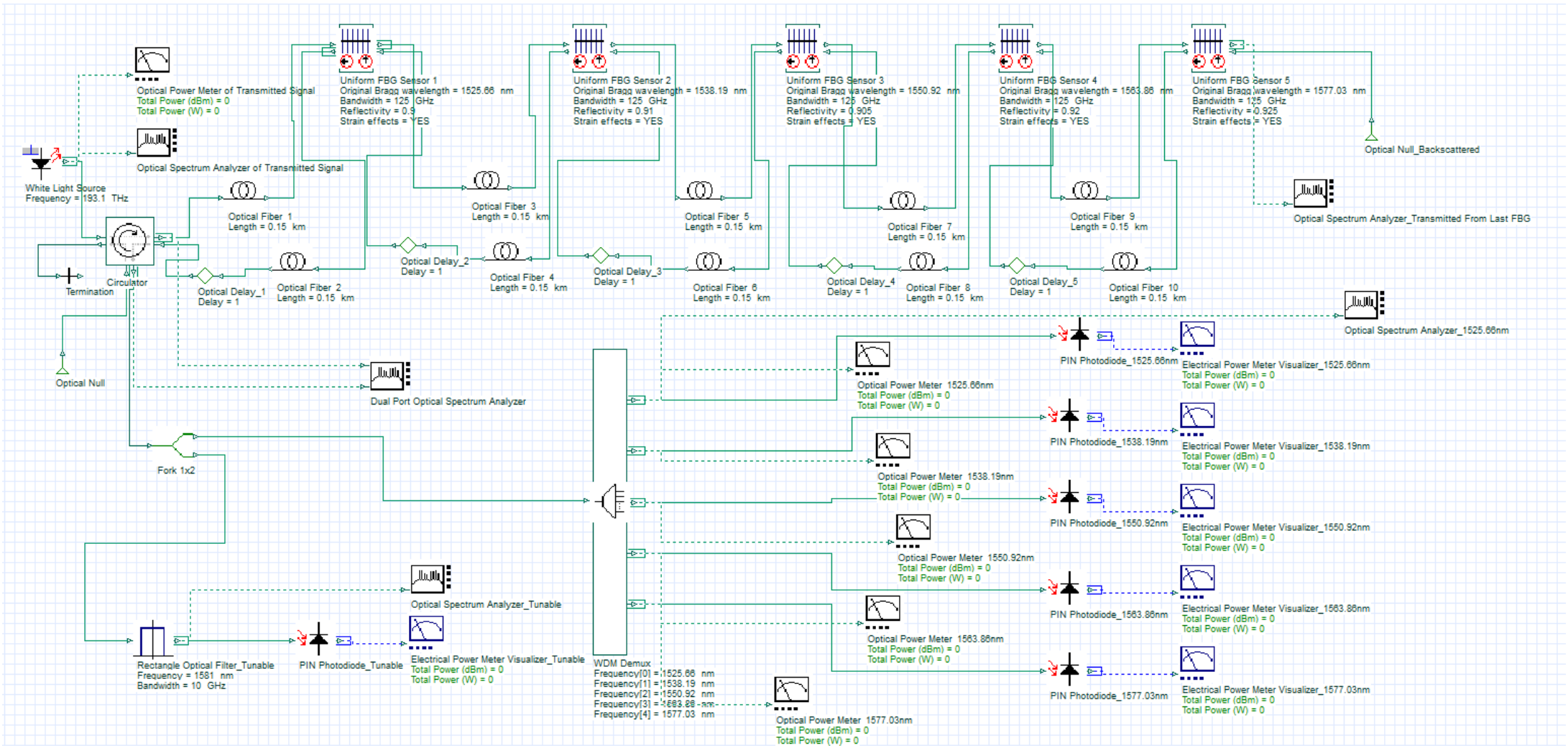


5G Fronthaul Downlink Transmitter*

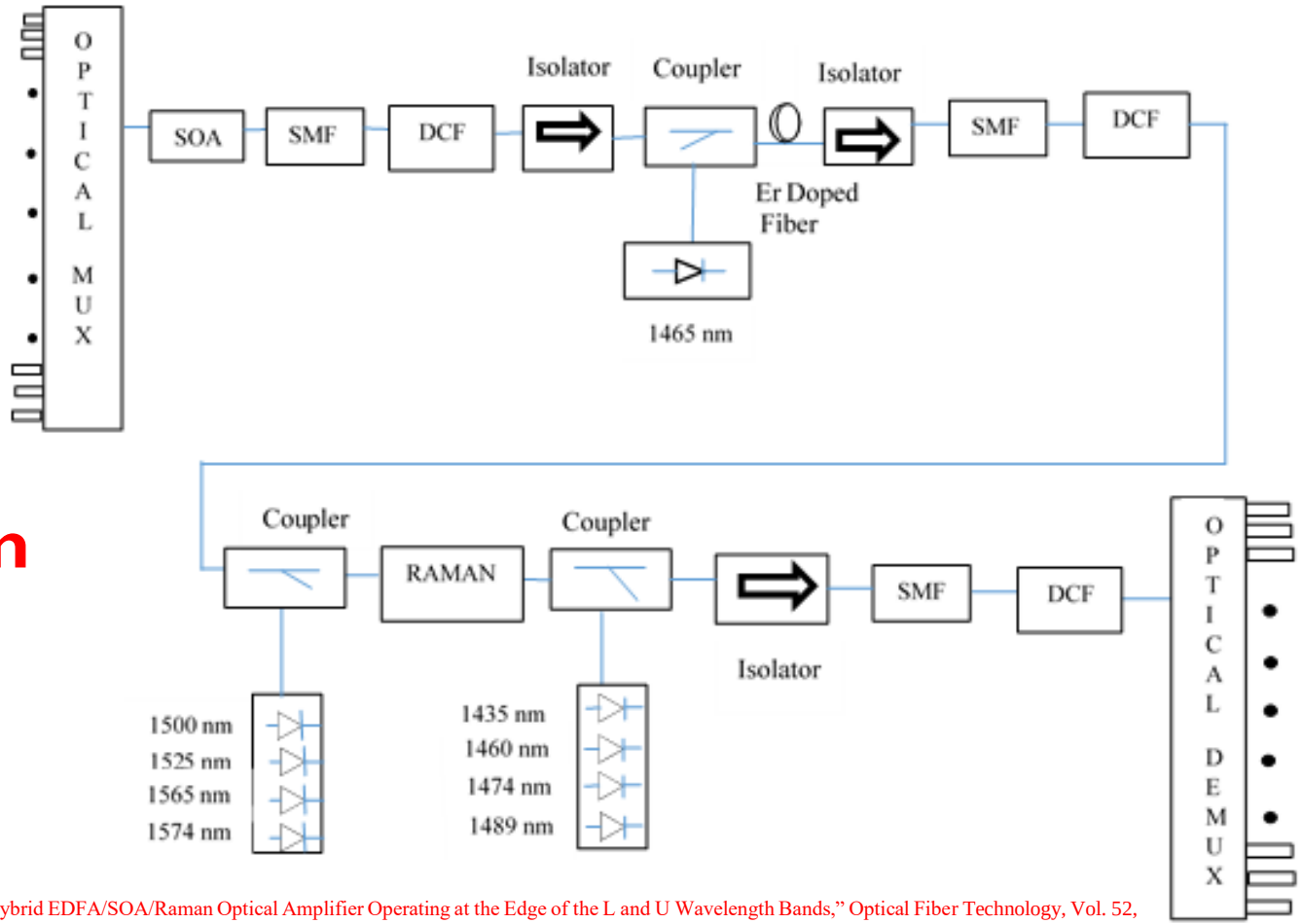


[*] Noweir, M., Zhou, Q., Kwan, A., Valivarthi, R., Helaoui, M., Tittel, W & Ghannouchi, F. M, "Digitally linearized radio-over fiber transmitter architecture for cloud radio access network's downlink," *IEEE Transactions on Microwave Theory and Techniques*, *66*(7), 3564-3574, (2018).

Railway Sensing Project



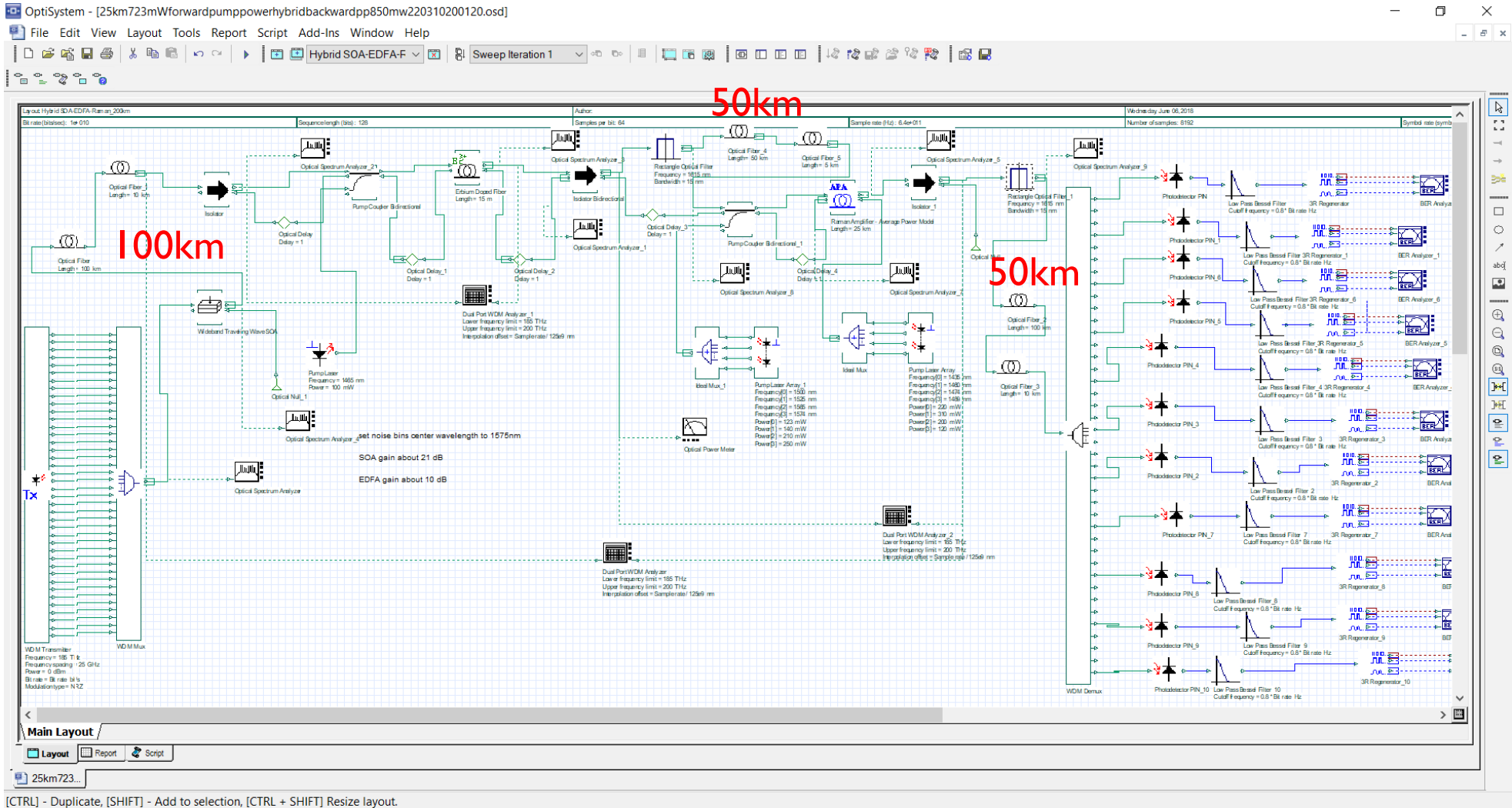
HYBRID SOA/EDFA/RAMAN OPTICAL AMPLIFIER*



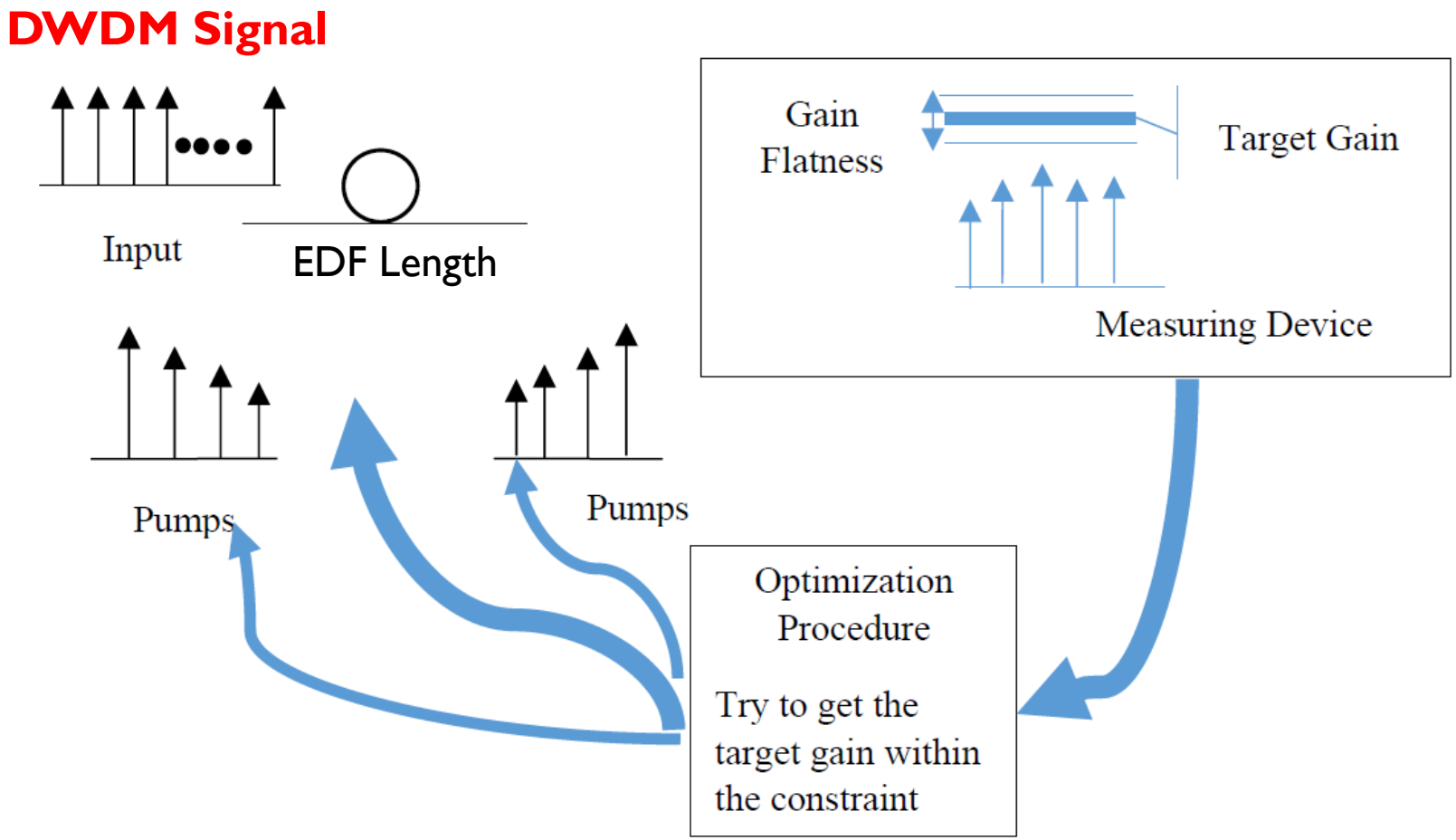
Optical DWDM System at Edge of L&U Bands

[*] Ajaybeer Kaur, Manjit Singh Bhamrah, Ahmad Atieh, "Very High Flat-Gain Hybrid EDFA/SOA/Raman Optical Amplifier Operating at the Edge of the L and U Wavelength Bands," Optical Fiber Technology, Vol. 52, 101971, Jun 2019.

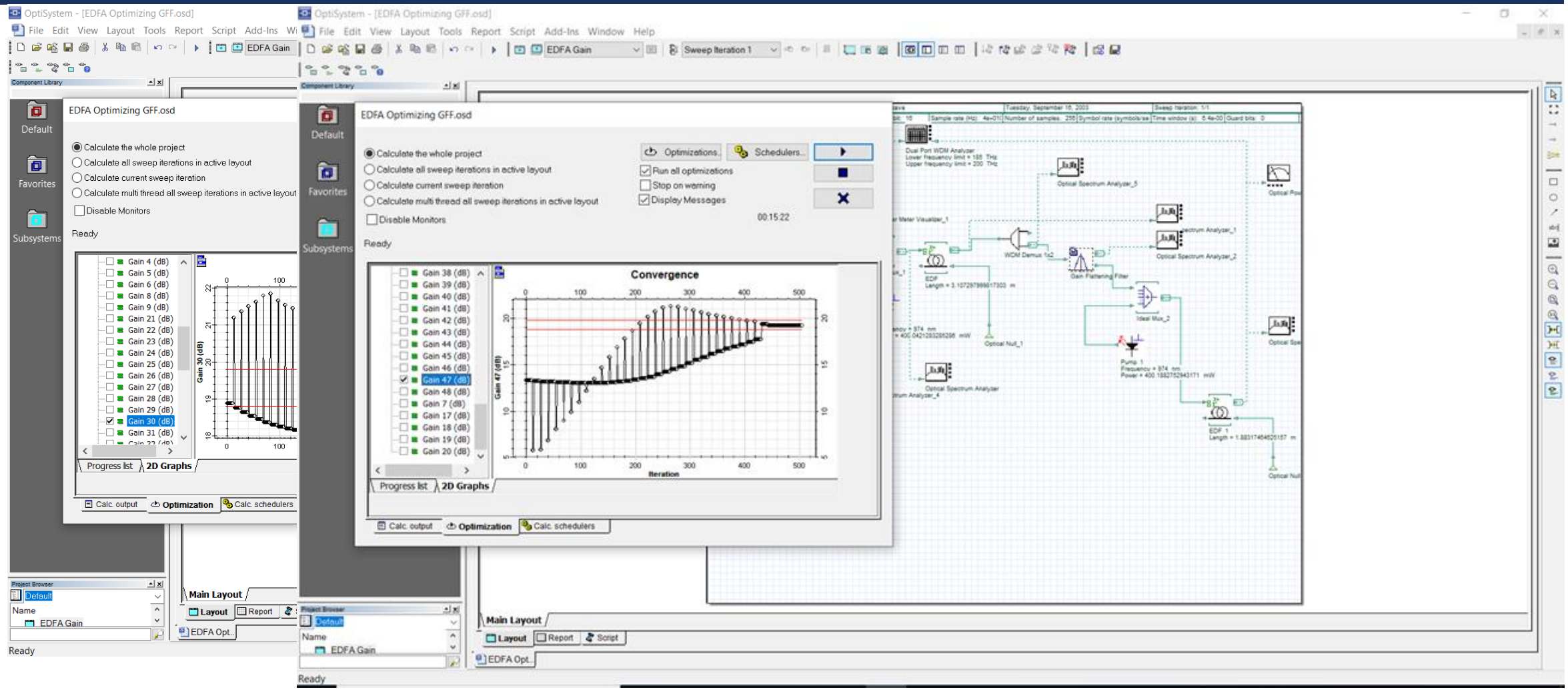
HOA DWDM TRANSMISSION SYSTEM



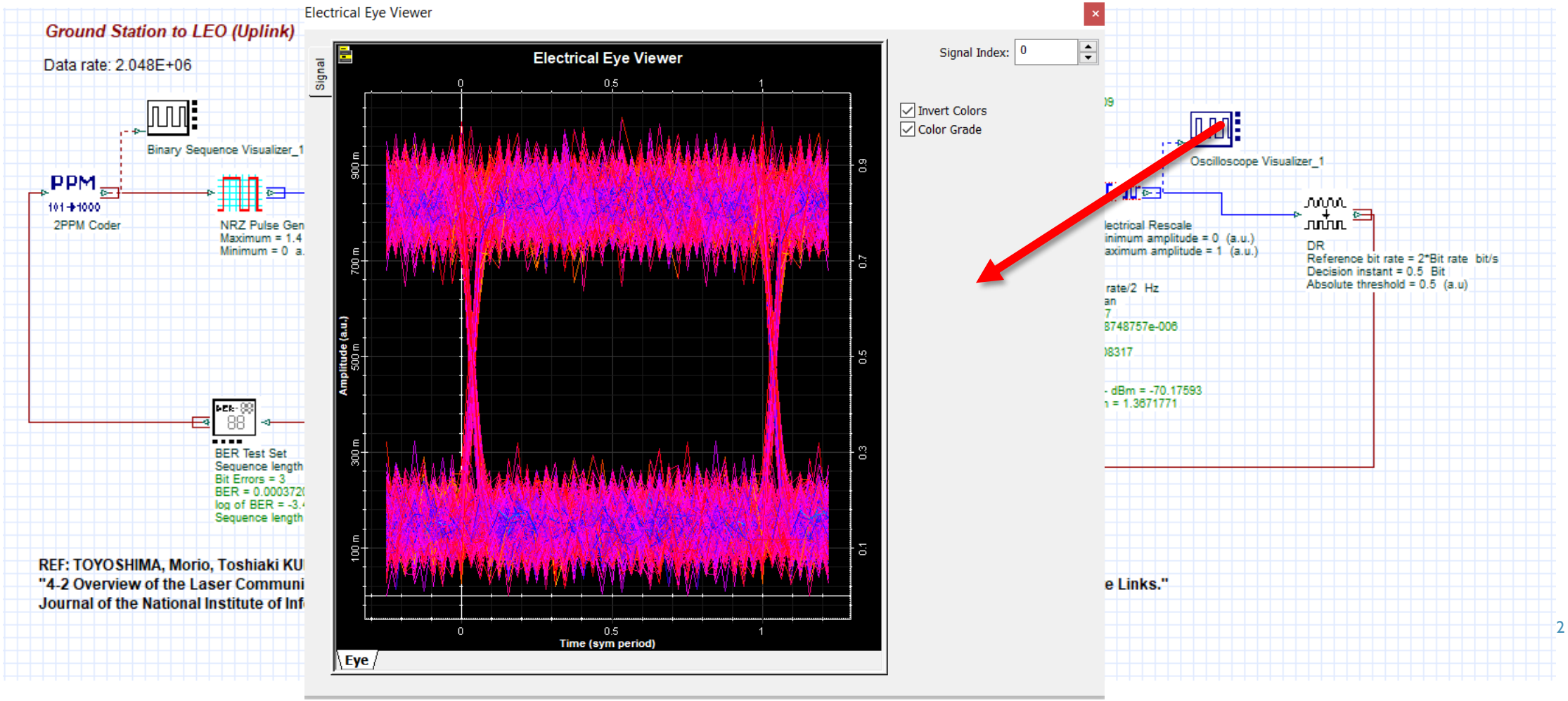
AMPLIFIER PARAMETERS OPTIMIZATION



OPTIMIZATION PROCESS



Satellite Communication



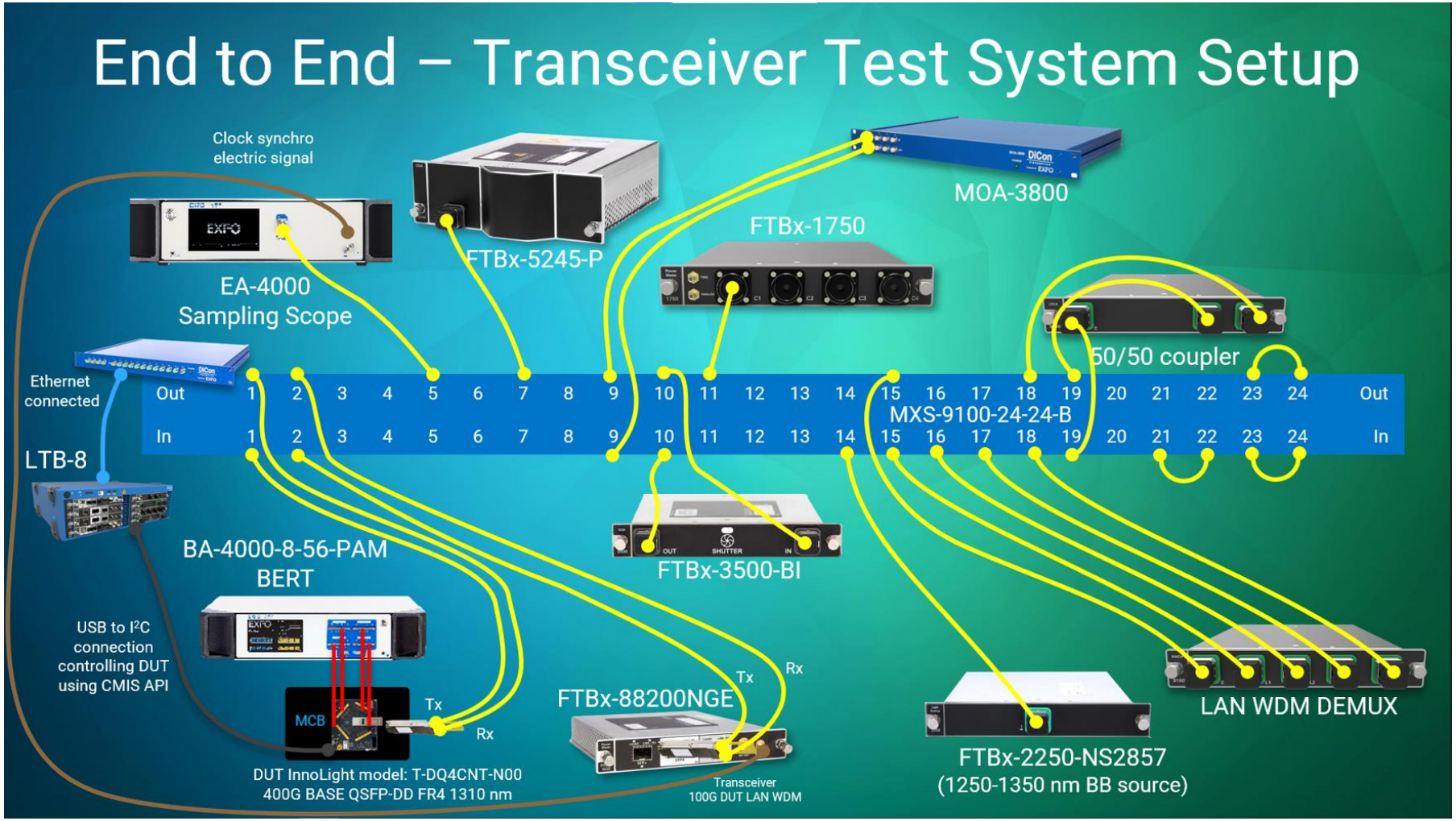
OPTIINSTRUMENT SOFTWARE IN ACTION

Communicate and Control equipment form Different Vendors

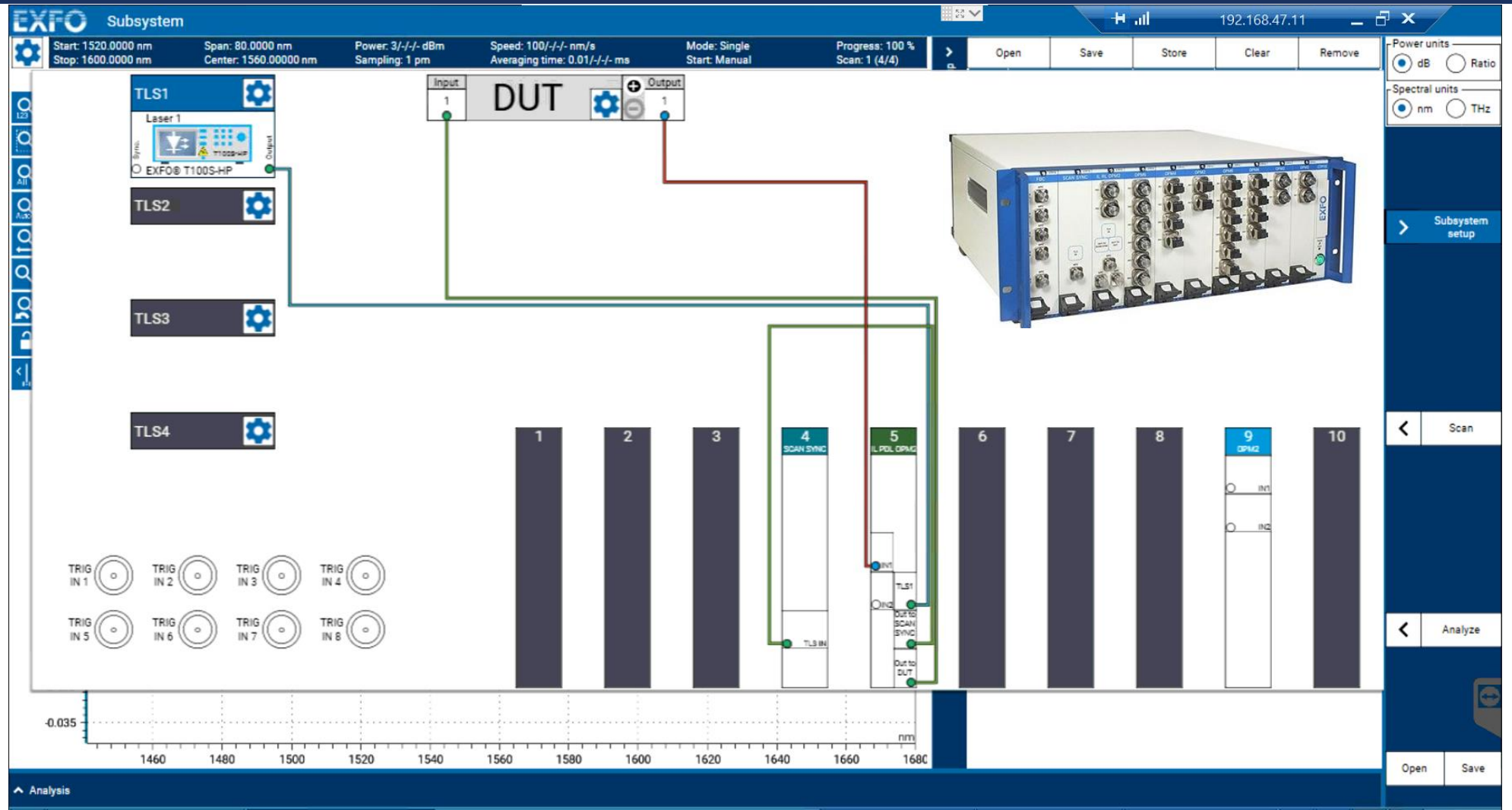
OPTIINSTRUMENT FEATURES & APPLICATIONS

- Remote/Co-location communication and control of instruments
- Set-up parameters of equipment
- Automate testing and characterization of devices using Instruments from same or different vendors
- Capture data, process, save and display single or multi-signals
- Saved data can be in JSON, .txt or CSV format
- User Raw Data Acquisition and Processing Python file
- SCPI Command Execution (py visa/NI visa) in Single Command Window
- Custom Python file(s) loading to build command sequence

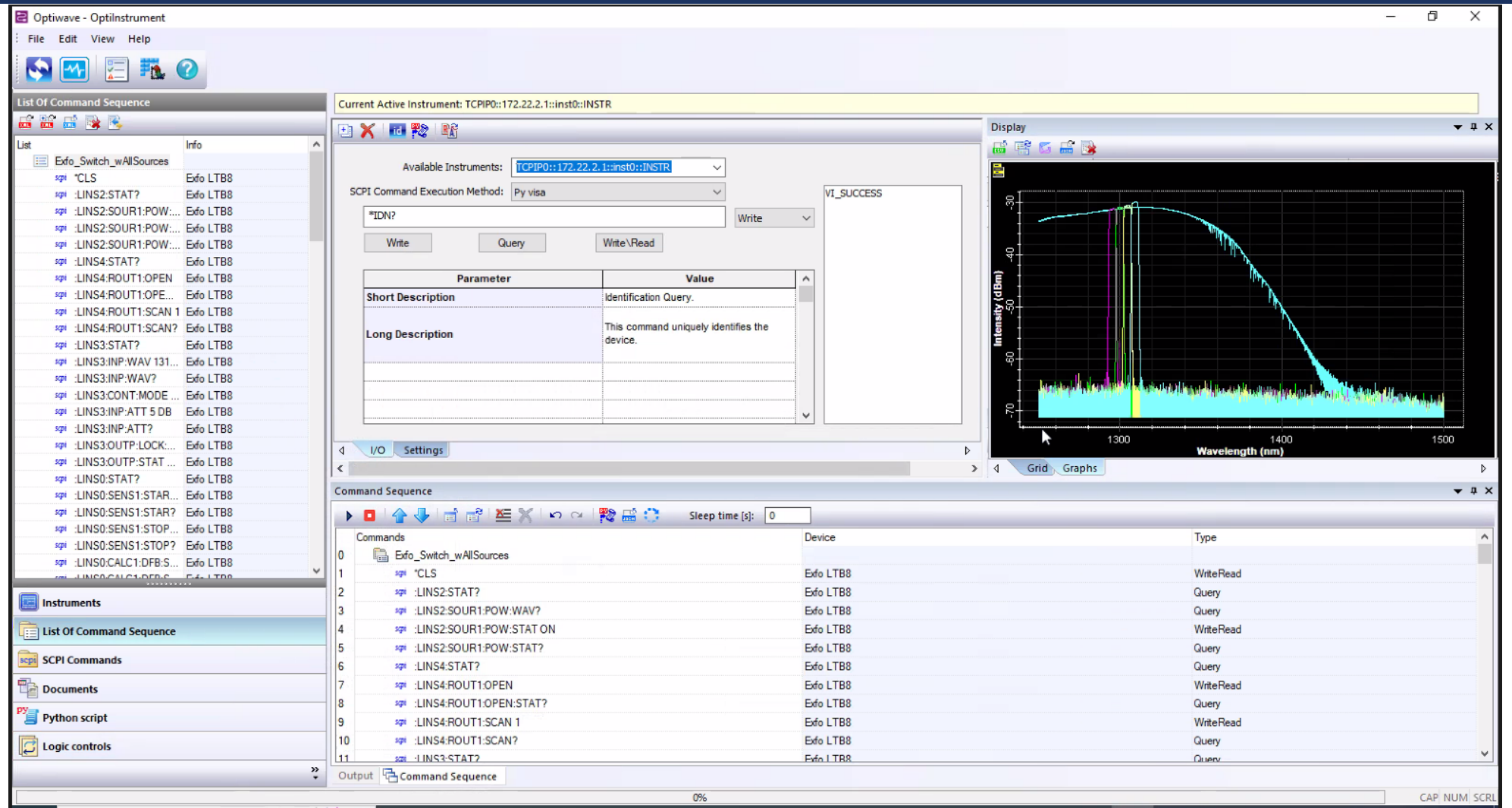
LTB-8 REMOTE SETUP QUEBEC CITY/CANADA



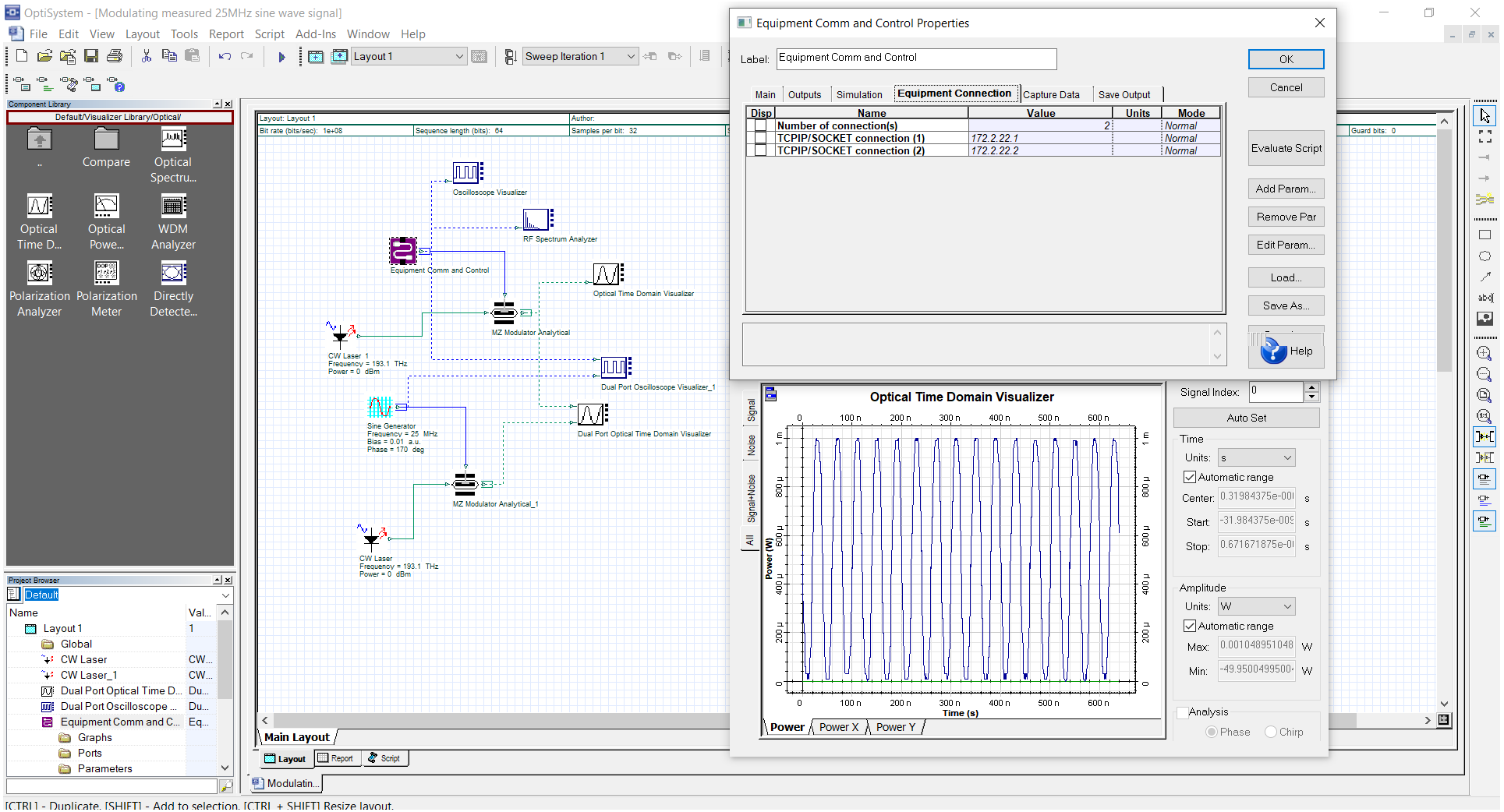
EXFO CTTP-10 EQUIPMENT GUI



OPTIINSTRUMENT 4.0 GUI

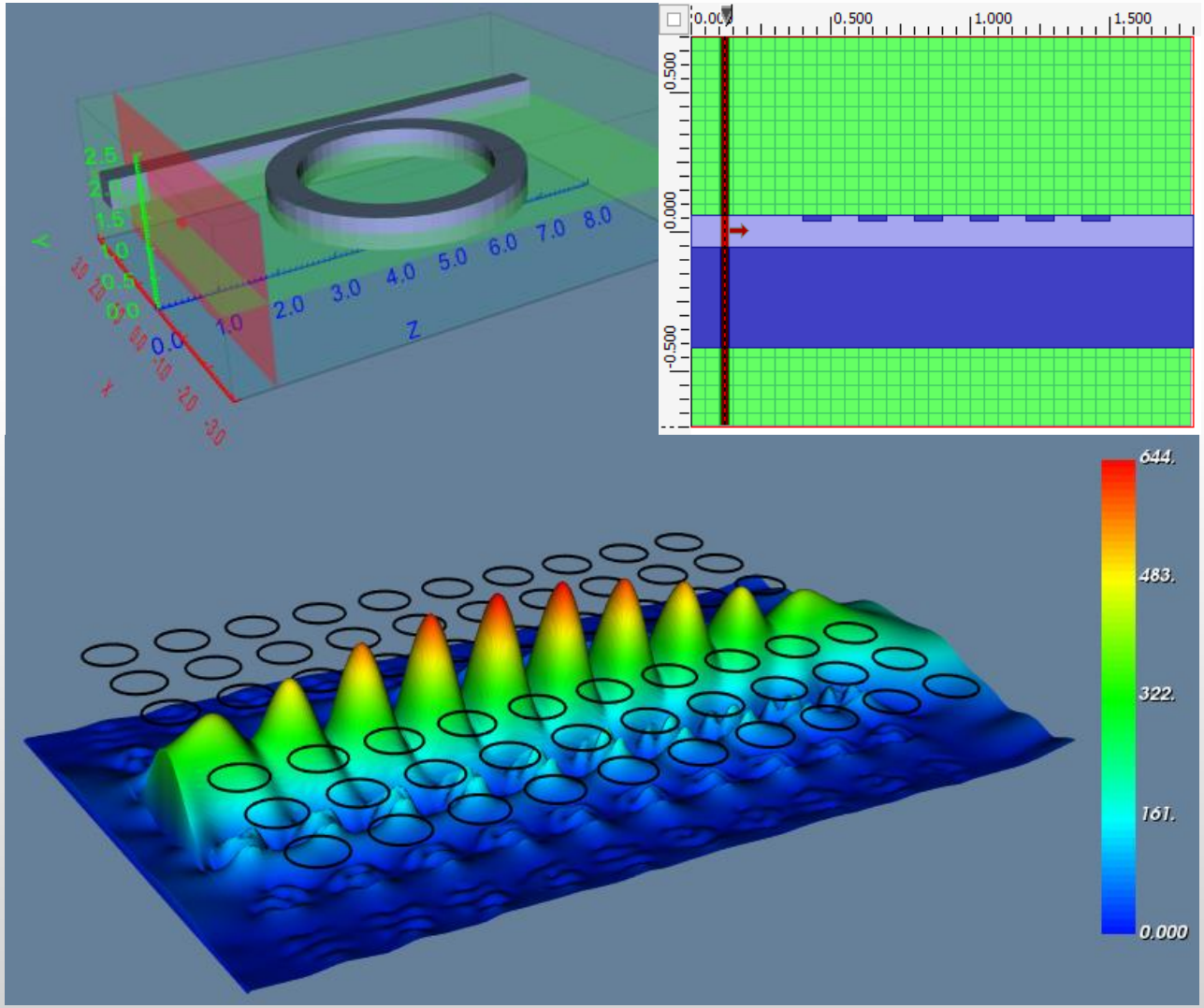


OPTISYSTEM CALLS OPTIINSTRUMENT



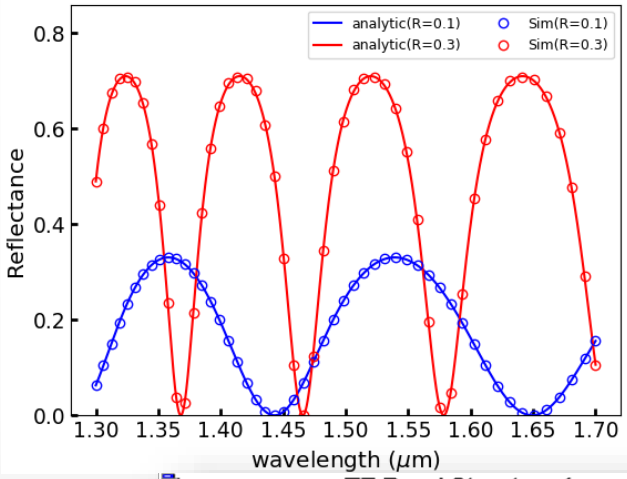
OptiFDTD – Finite-Difference Time-Domain Package

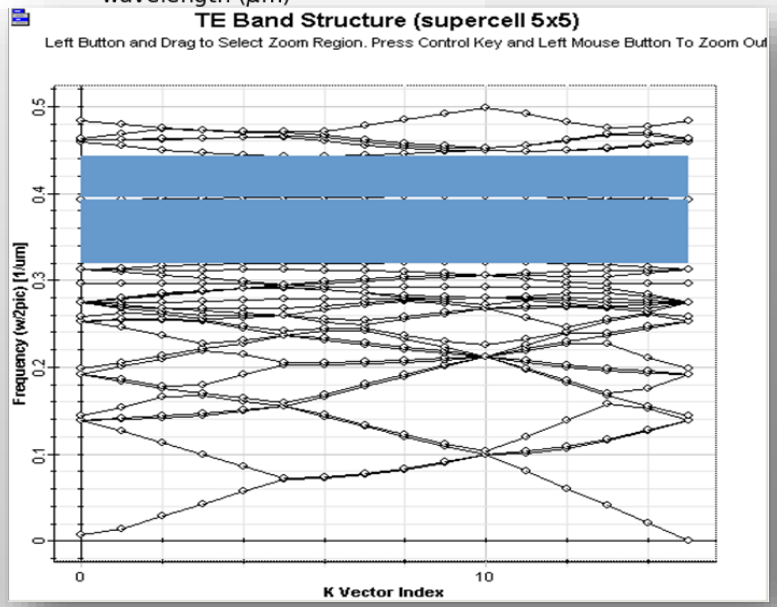
OPTIFDTD



- Finite-Difference Time-Domain: discretization of Maxwell's equations and the simulation domain in both time and space
- Robust simulation engine providing full vector field information
- Minimal assumptions in theoretical development
- Natively supports bi-directional propagation, resonators and meta-surfaces and photonic crystals

OPTIFDTD

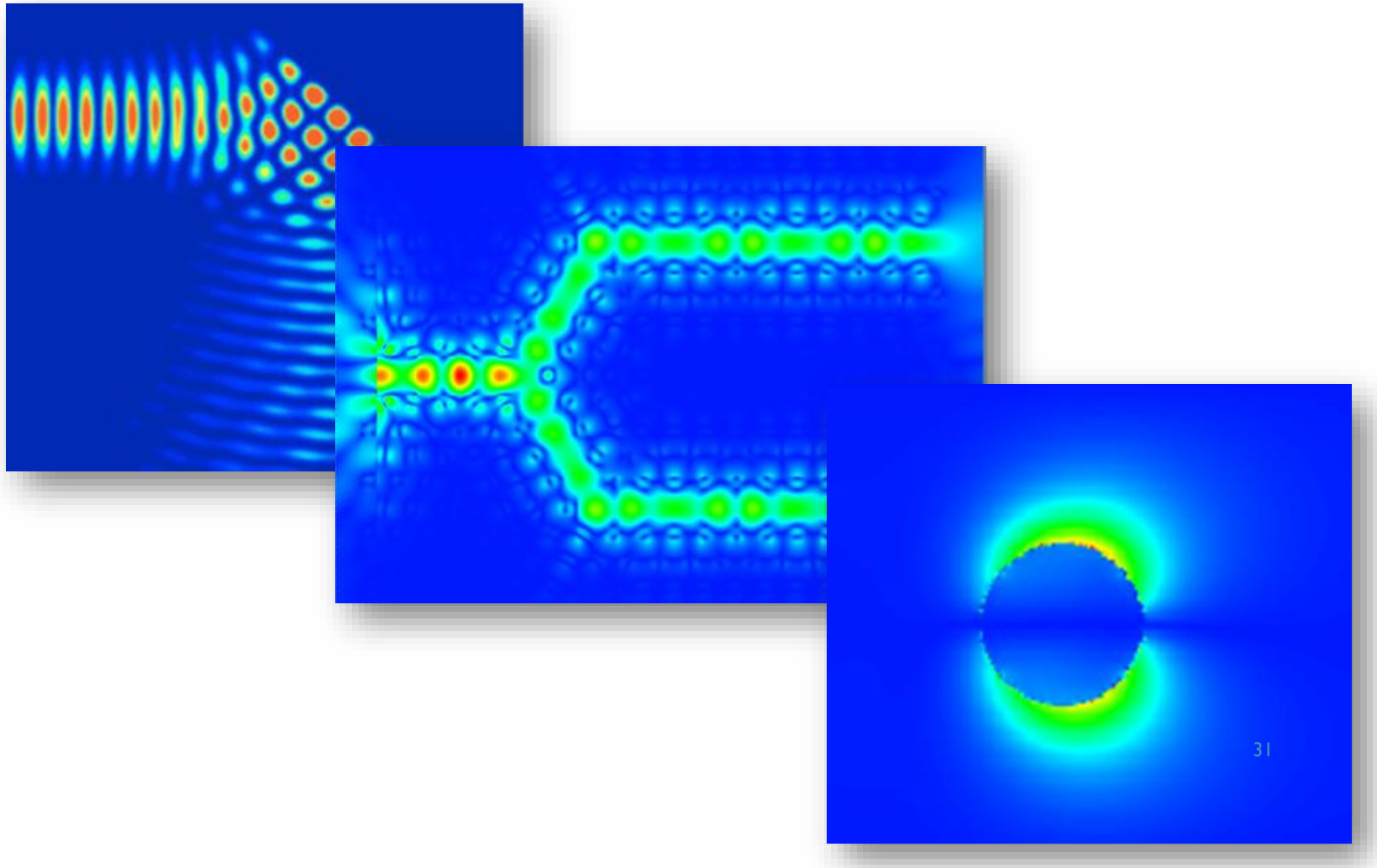




- Sources (Rectangular, Gaussian, Point, Advanced mode injection, User-defined field injection)
- Pulse source in time provides spectral analysis with a single simulation
- Materials (Constant dielectric, dispersive, 2D non-linear)
- Components (3D structures, waveguides, CAD import, Mask import)
- Observers (Point, Line, Area)
- S-Parameter support for integration with other modelling software (OptiSpice)
- Planewave expansion analysis for photonic crystals
- Parameterization of design
- VBScripting for powerful support for dynamic design and analysis

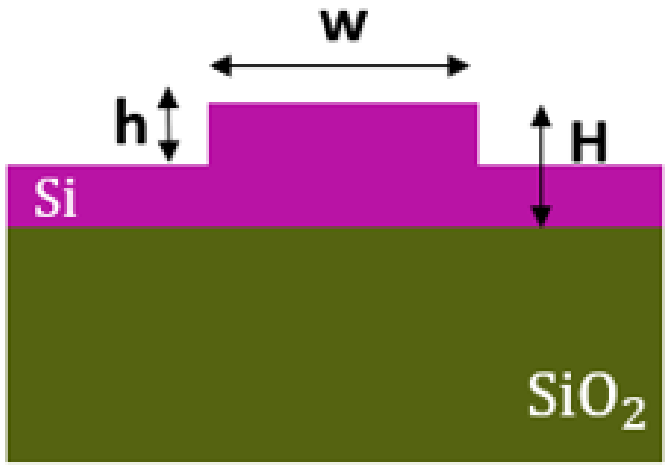
OPTIFDTD – SELECT APPLICATIONS

- Dielectric and metallic gratings
- CMOS sensors design
- Photonic crystals
- Integrated optics
- Optical filters and resonators
- Solar cells
- LED and OLED passive design
- Plasmonics
- Surface Plasmon Resonance
- Nanoparticles simulations
- Diffractive micro-optics elements

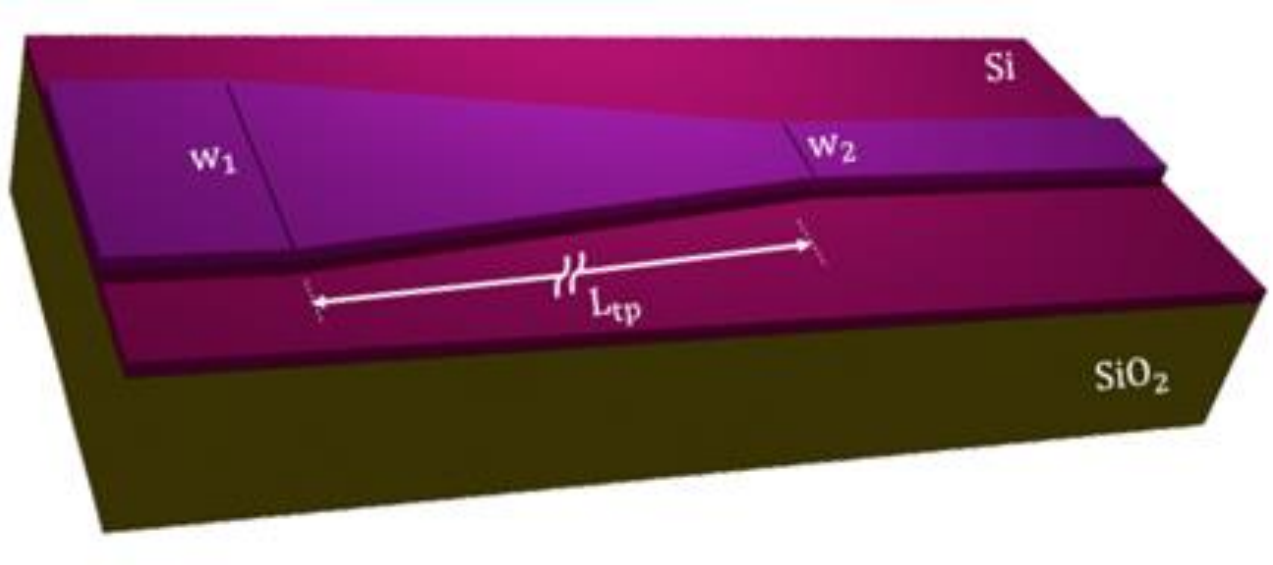


POLARIZATION CONVERTER

SOI Ridge Waveguide



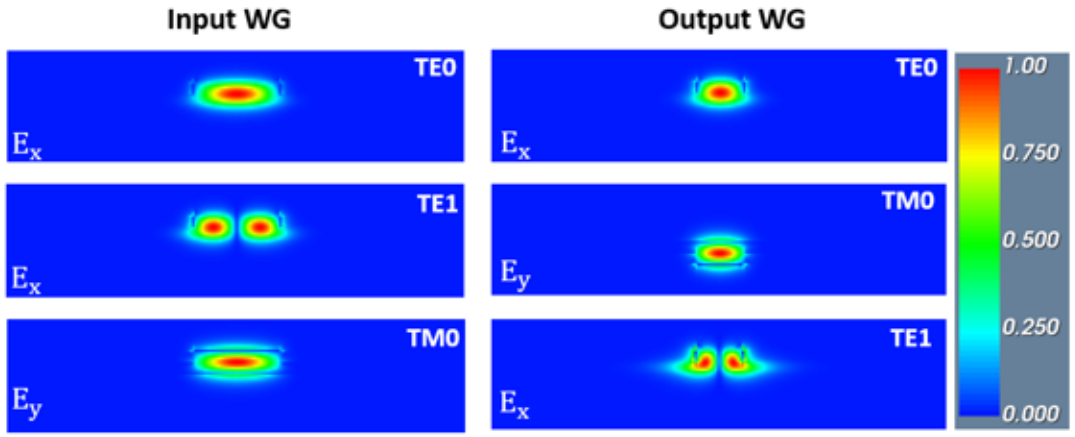
Waveguides

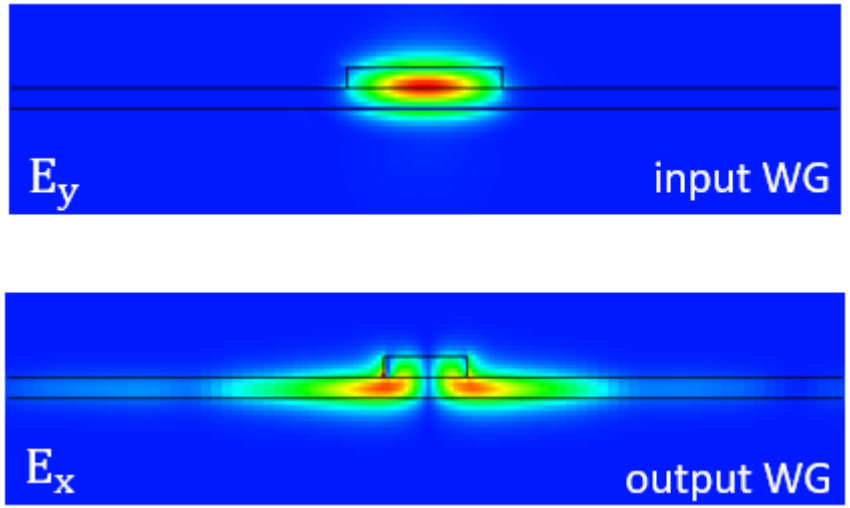


D. Dai, Y. Tang, and J. E. Bowers. "Mode conversion in tapered submicron silicon ridge optical waveguides," Optics express, Vol. 20, No. 12, pp. 13425-13439, 2012.

D. Vermeulen, K. V. Acoleyen, S. Ghosh, W. D. Cort, N. A. Yebo, E. Hallynck, K. D. Vos et al. "Efficient tapering to the fundamental quasi-TM mode in asymmetrical waveguides," In 15th European conference on Integrated Optics (ECIO), 2010.

POLARIZATION CONVERTER

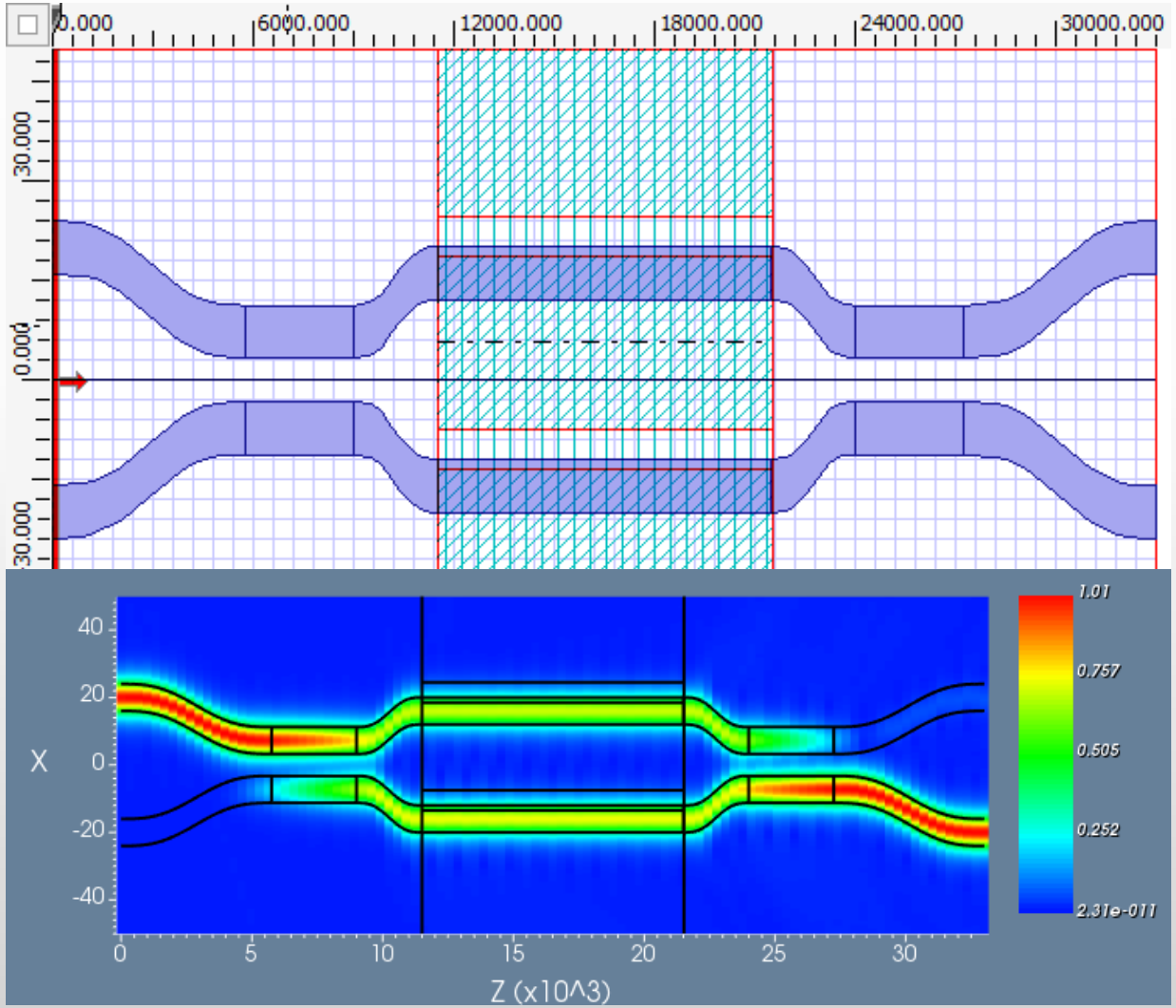




Optiwave
DESIGN SOFTWARE

OptiBPM – Beam Propagation Package

OPTIBPM



- Beam Propagation Method (BPM)
- Specifically targeting guiding, coupling, switching, splitting, multiplexing, and demultiplexing of optical signals in photonic devices
- Support for modelling diffused LiNbO3 waveguides and electrodes including physical diffusion parameters
- Parameterization of design
- VBScripting for powerful support for dynamic design and analysis

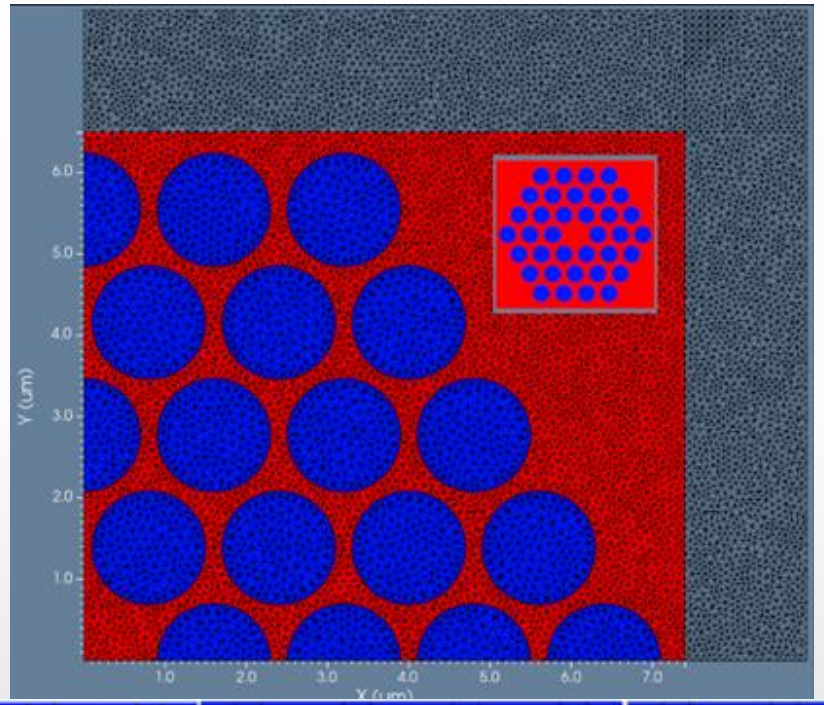
OPTIBPM – SELECT APPLICATIONS

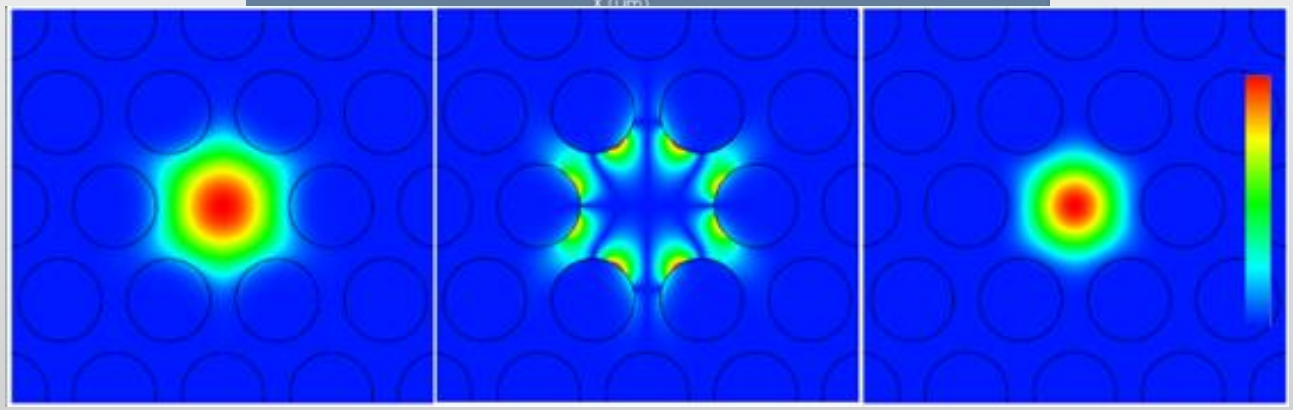
- Design optical splitters, combiners, couplers, multiplexers, and modulators.
- Large scale optical circuit design capabilities
- Model non-symmetrical waveguide structures
- Channel, rib or ridge waveguide design
- Buried waveguides
- Waveguides from a diffused process
- Sensor structures

Optiwave
DESIGN SOFTWARE

OptiMode – Mode Solver Package

OPTIMODE





- Advanced mode solving package
- Available as a stand along product and integrated with OptiFDTD / OptiBPM for direct mode injection
- Multiple algorithms (ADI, Aniso, FD, and FEM)
- Support for constant dielectric, diffused waveguide, and electrodes
- Parameterization of design
- VBScripting for powerful support for dynamic design and analysis

Optiwave

DESIGN SOFTWARE

OptiSPICE and Plugins

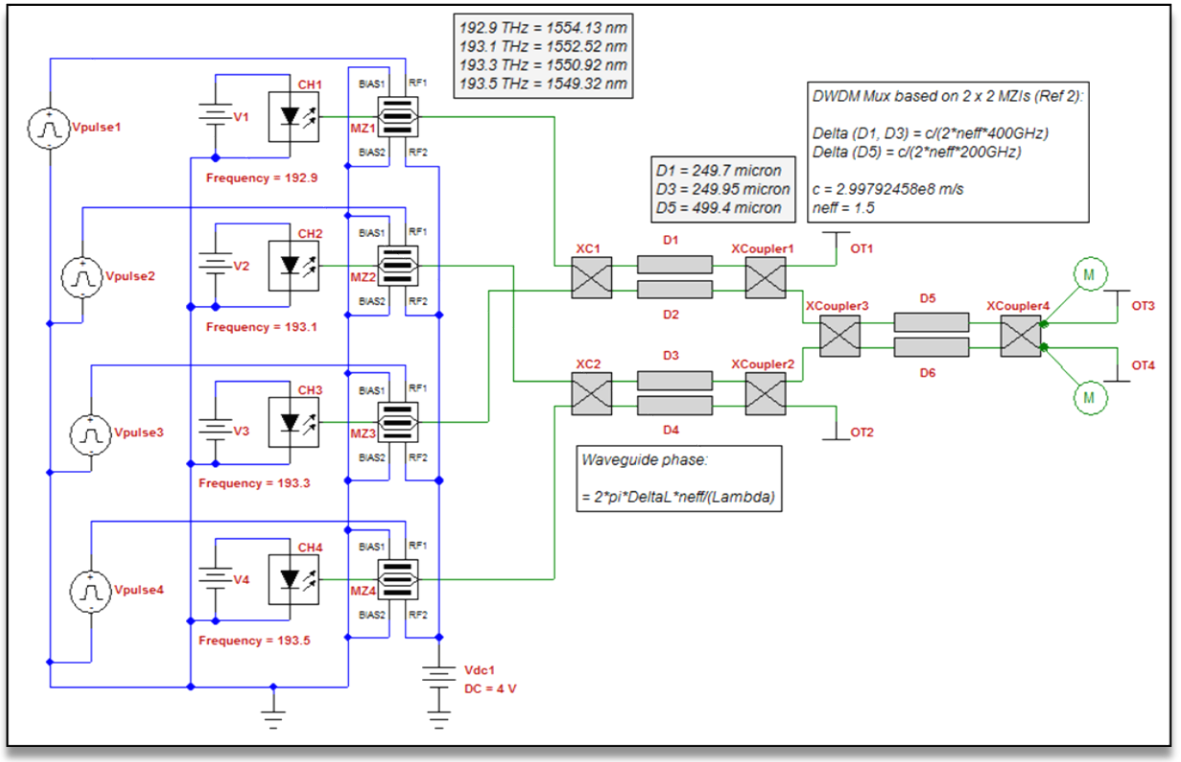
Opto-Electronic Circuit Design Simulator

Contents

- OptiSPICE Overview
- OptiSPICE Standalone vs Plugin
- Application Examples in OptiSPICE Standalone
  - Optical Phase Locked Loop for Homodyne Detection
  - Optical Link Co-Simulation with OptiSystem
- Application Examples using OptiSPICE Plugin in Siemens EDA
  - Higher Order Flat-Top Filter Using S-parameter Model
  - OptiSPICE Plugin – Siemens EDA Tanner Workflow
- PDK Support

OptiSPICE Overview

- A fully integrated Spice engine based opto-electronics circuit simulator based on modified nodal analysis (MNA)
- Self consistent solution with Newton Raphson iterations
- Set of linear (R,L,C etc..) and nonlinear (BJT, MOSFET etc..) electrical models
- Multi-mode, multi-channel, bidirectional linear (splitter, joiner etc...) and non linear optical models (laser, optical fiber etc..)
- Time and frequency domain solutions and wavelength sweeps
- Optical S-parameters based circuit simulations
- Model thermal behaviour of devices
- Optical-to-electrical S-parameter conversion
- Post-processing capabilities using Python and MATLAB



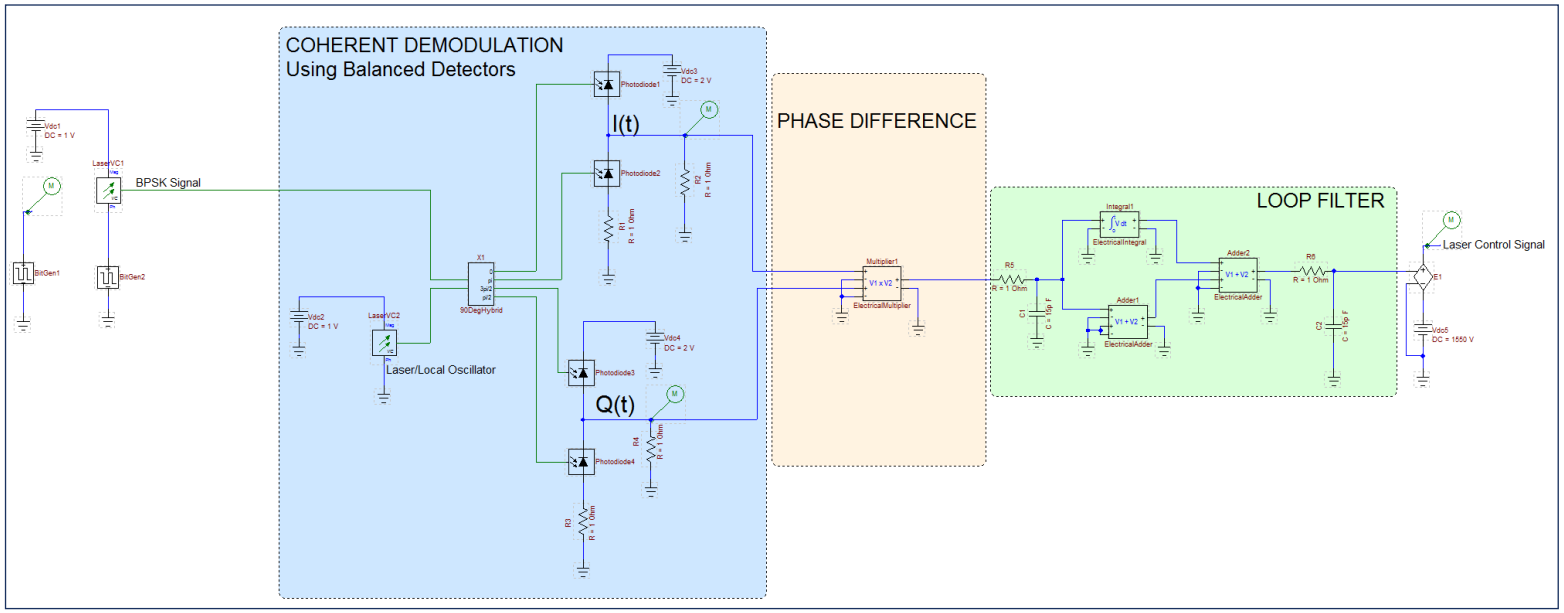
OptiSPICE Standalone vs. Plugin

OptiSPICE Standalone – Full solution for analog simulation of optoelectronic circuits and devices
OptiSPICE Plugin – Optical models addon for industry standard electrical design automation tools

	OptiSPICE Standalone	OptiSPICE Plugin
GUI	Optiwave	Siemens EDA
Visualization Tools	Optiwave	Siemens EDA
Electrical Model Library	Optiwave	Siemens EDA
Optical Model Library	Optiwave	Optiwave
Simulation Engine	Optiwave	Siemens EDA
Mask Layout & DRC Tool	NA	Siemens EDA
Optical PDK Compact Models	Optiwave	Optiwave

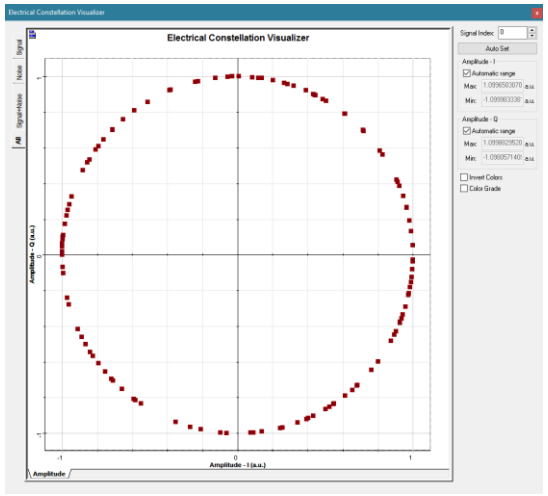
Optical Phase Locked Loop for Homodyne Detection

- Signal Generation and Detection
  - BPSK Signal Generator
  - Local Oscillator
  - 90 degree hybrid
  - Balanced detectors
- Phase Difference Calculation
  - Electrical multiplier
  - Detect Phase difference
- Feedback: Generating the control signal
  - Loop Filter
  - DC Offset
  - Generate Control Signal

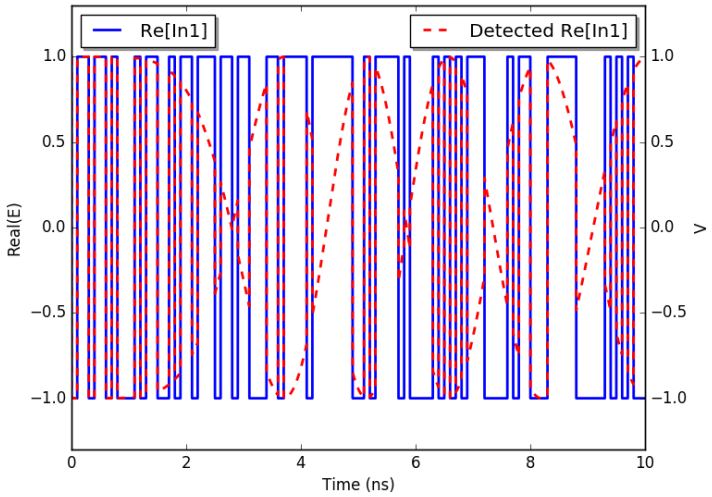


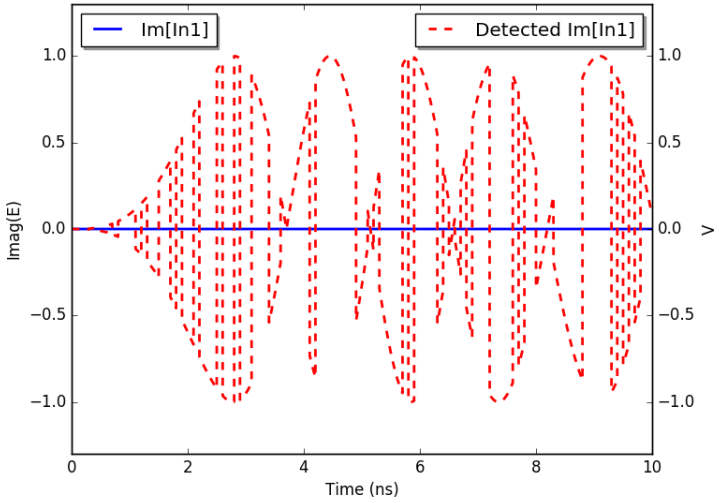
Optical Phase Locked Loop for Homodyne Detection

Without the active phase correction of the PLL a constant frequency difference between the local oscillator and the carrier signal detected I and Q do not have the correct phase (pi or –pi for BPSK). The constant frequency difference results in the rotation of the constellation diagram



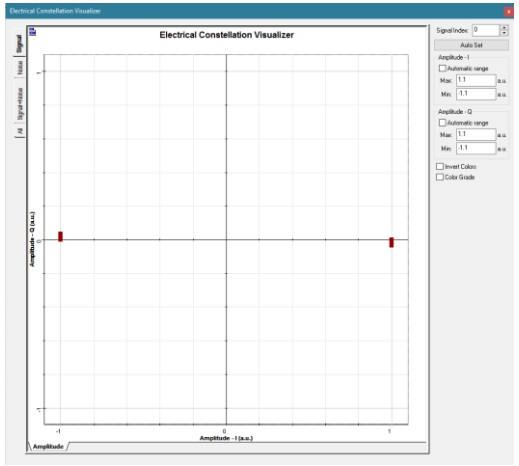
Phase Locked Loop OFF



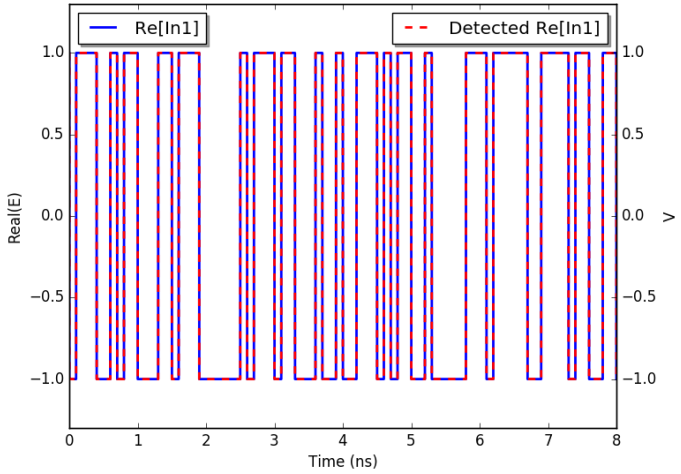


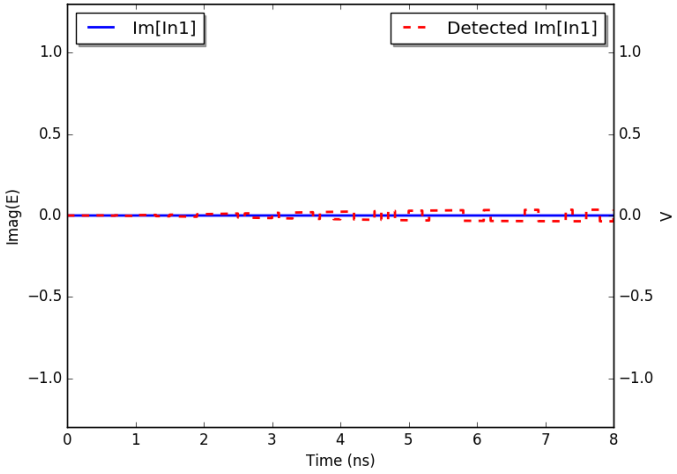
Optical Phase Locked Loop for Homodyne Detection

When the PLL is activated the frequency/phase of the local oscillator tracks the frequency/phase of the carrier signal. Therefore the detected I and Q have the right phase and the constellation diagram does not rotate

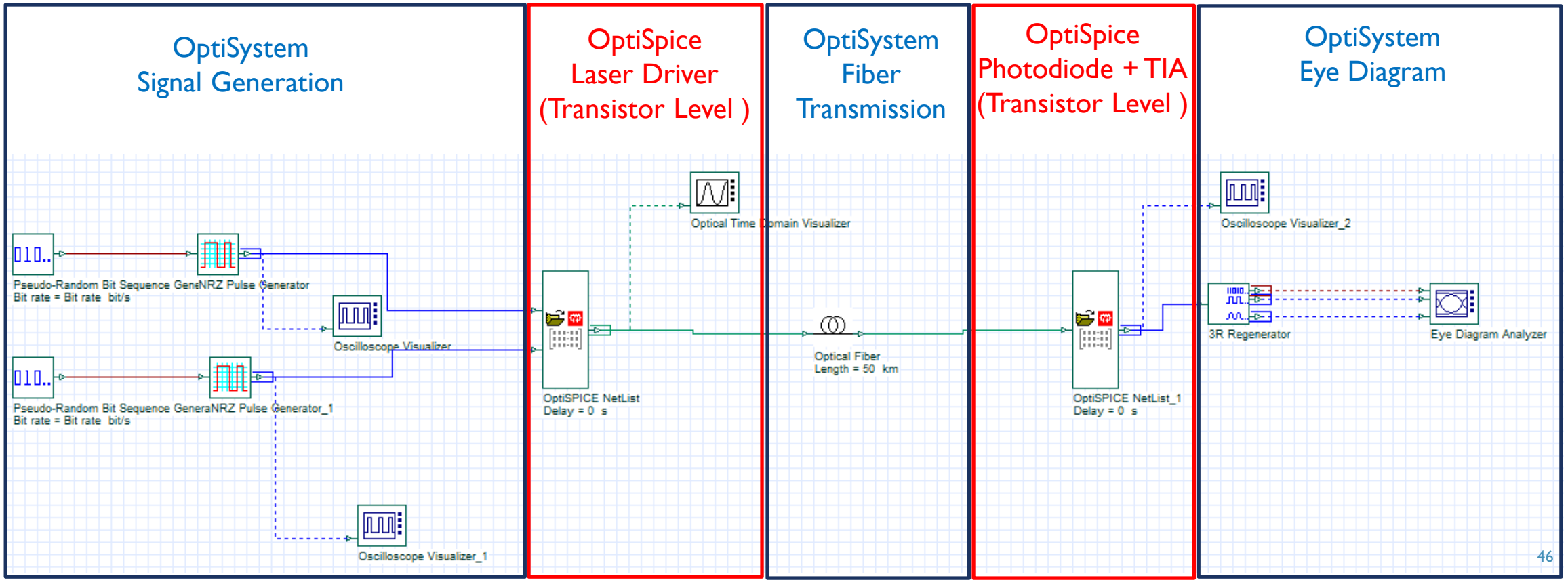


Phase Locked Loop ON

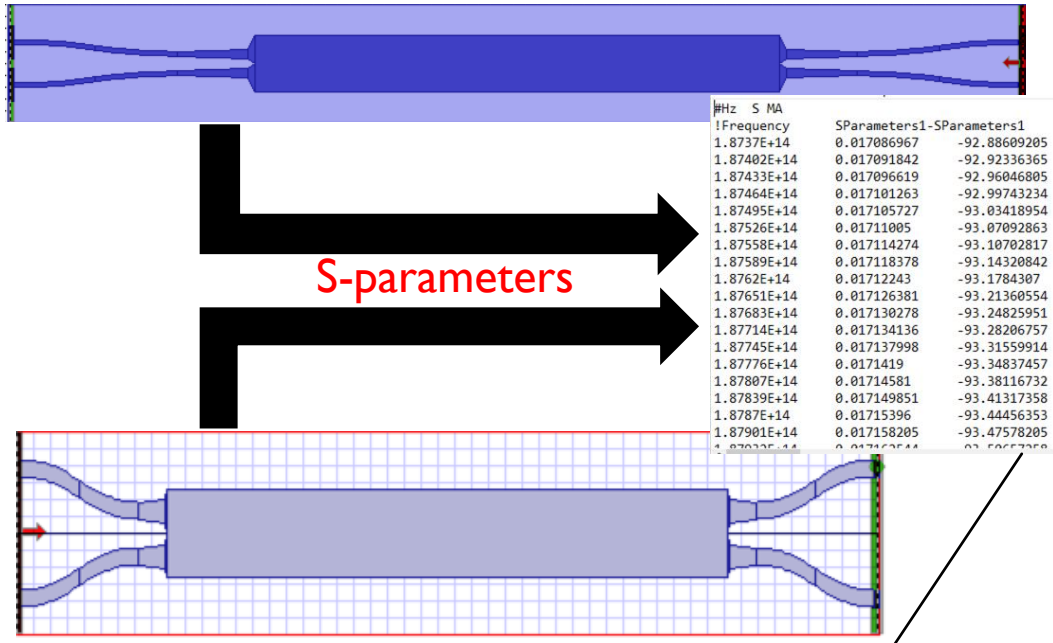




Optical Link Co-Simulation with OptiSystem



Higher Order Flat-Top Filter Using S-parameter Model

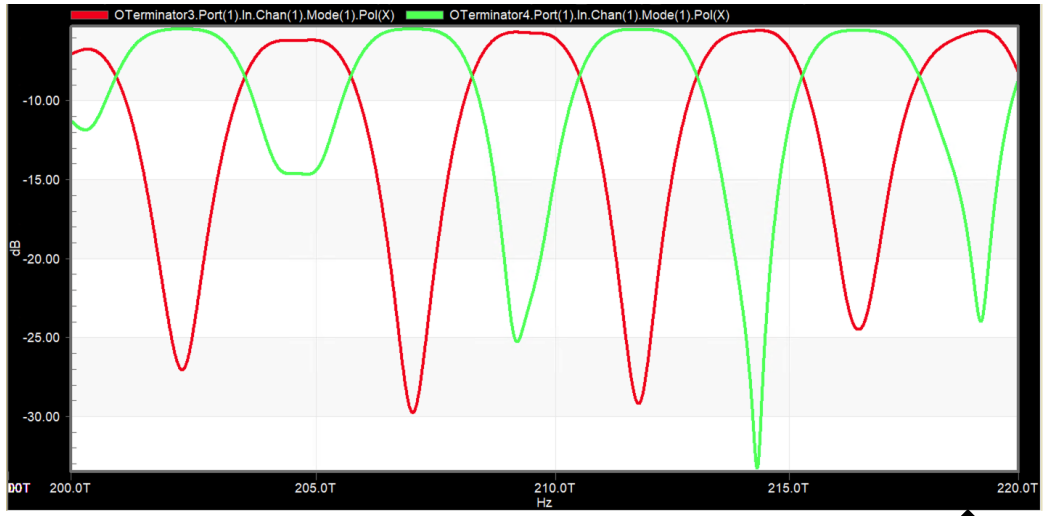


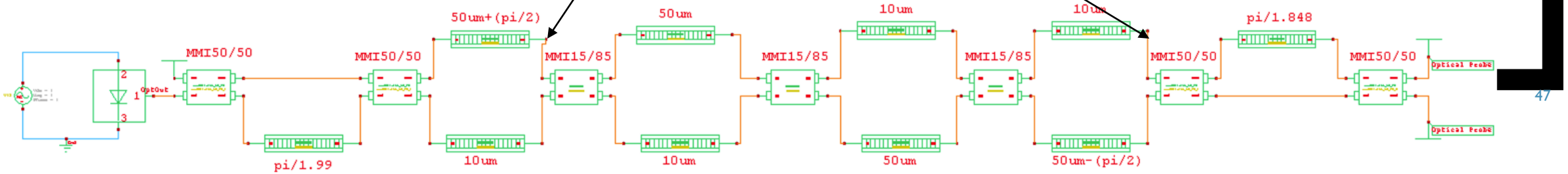
S-parameters

#Hz S MA

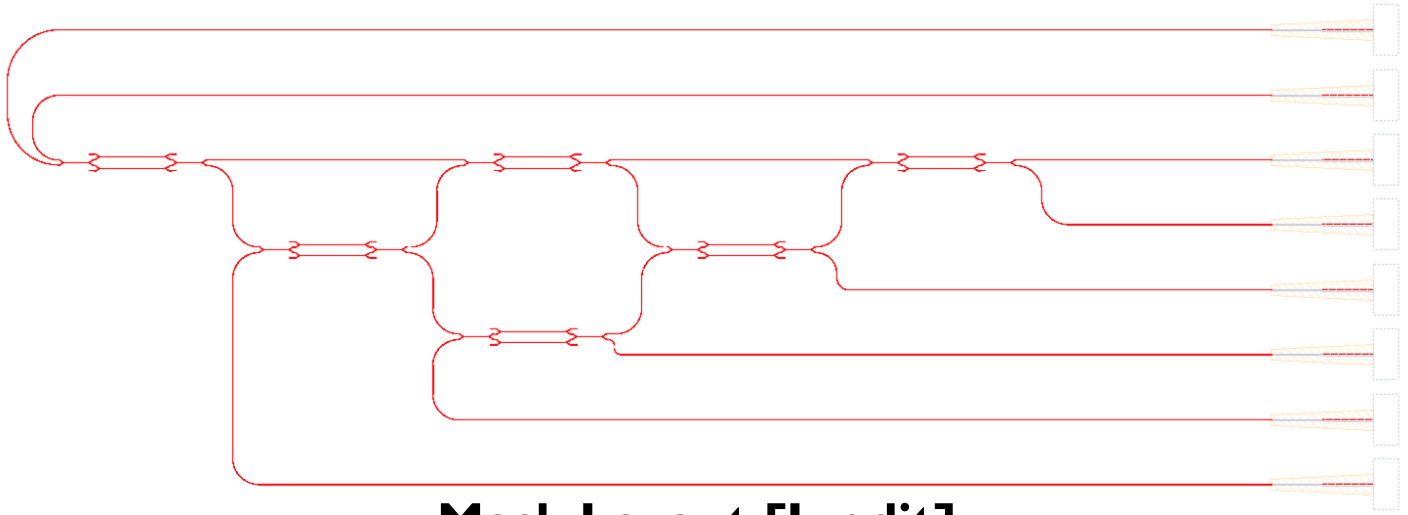
!Frequency	SParameters1-SParameters1		SParameters1-SParameters2		
1.8737E+14	0.017086967	-92.88609205	9.94691E-05	69.62124476	0
1.87402E+14	0.017091842	-92.92336365	9.94741E-05	69.64843865	0
1.87433E+14	0.017096619	-92.96046805	9.94899E-05	69.67778572	0
1.87464E+14	0.017101263	-92.99743234	9.95168E-05	69.70820675	0
1.87495E+14	0.017105727	-93.03418954	9.95551E-05	69.73864765	0
1.87526E+14	0.01711005	-93.07092863	9.96045E-05	69.76805016	0
1.87558E+14	0.017114274	-93.10702817	9.96648E-05	69.7953291	0
1.87589E+14	0.017118378	-93.14320842	9.97351E-05	69.81955383	0
1.8762E+14	0.01712243	-93.1784307	9.98146E-05	69.83985512	0
1.87651E+14	0.017126381	-93.21360554	9.99019E-05	69.85534612	0
1.87683E+14	0.017130278	-93.24825951	9.99957E-05	69.86555166	0
1.87714E+14	0.017134136	-93.28206757	0.000100094	69.8697639	0
1.87745E+14	0.017137998	-93.31559914	0.000100196	69.86763763	0
1.87776E+14	0.0171419	-93.34837457	0.000100299	69.85900059	0
1.87807E+14	0.01714581	-93.38116732	0.000100402	69.84391777	0
1.87839E+14	0.017149851	-93.41317358	0.000100503	69.82244584	0
1.8787E+14	0.01715396	-93.44456353	0.000100599	69.79496128	0
1.87901E+14	0.017158205	-93.47578205	0.00010069	69.76172775	0

Transmission Response



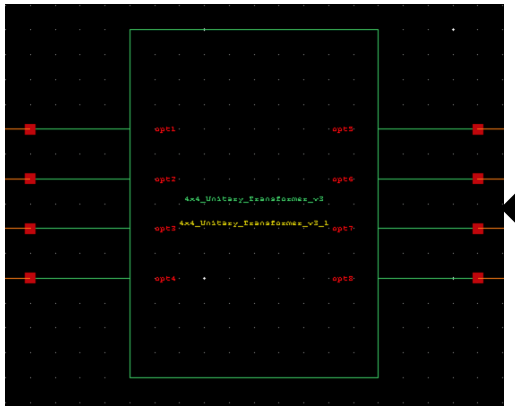


OptiSPICE Plugin – Siemens EDA Tanner Workflow



Mask Layout [L-edit]

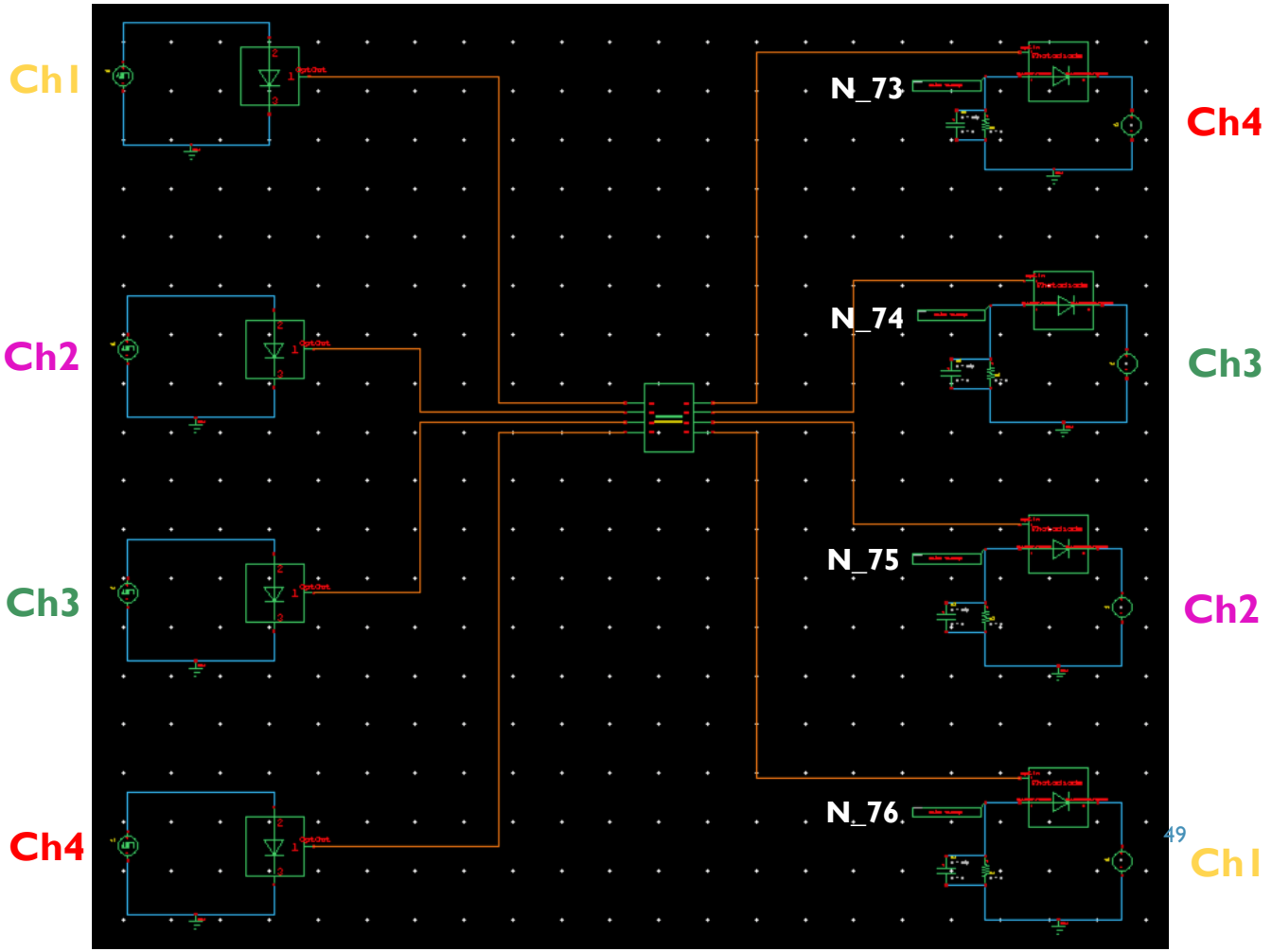
Circuit Netlist [L-edit]



Equivalent Sub-Circuit [S-edit]

OptiSPICE Plugin – Siemens EDA Tanner Workflow

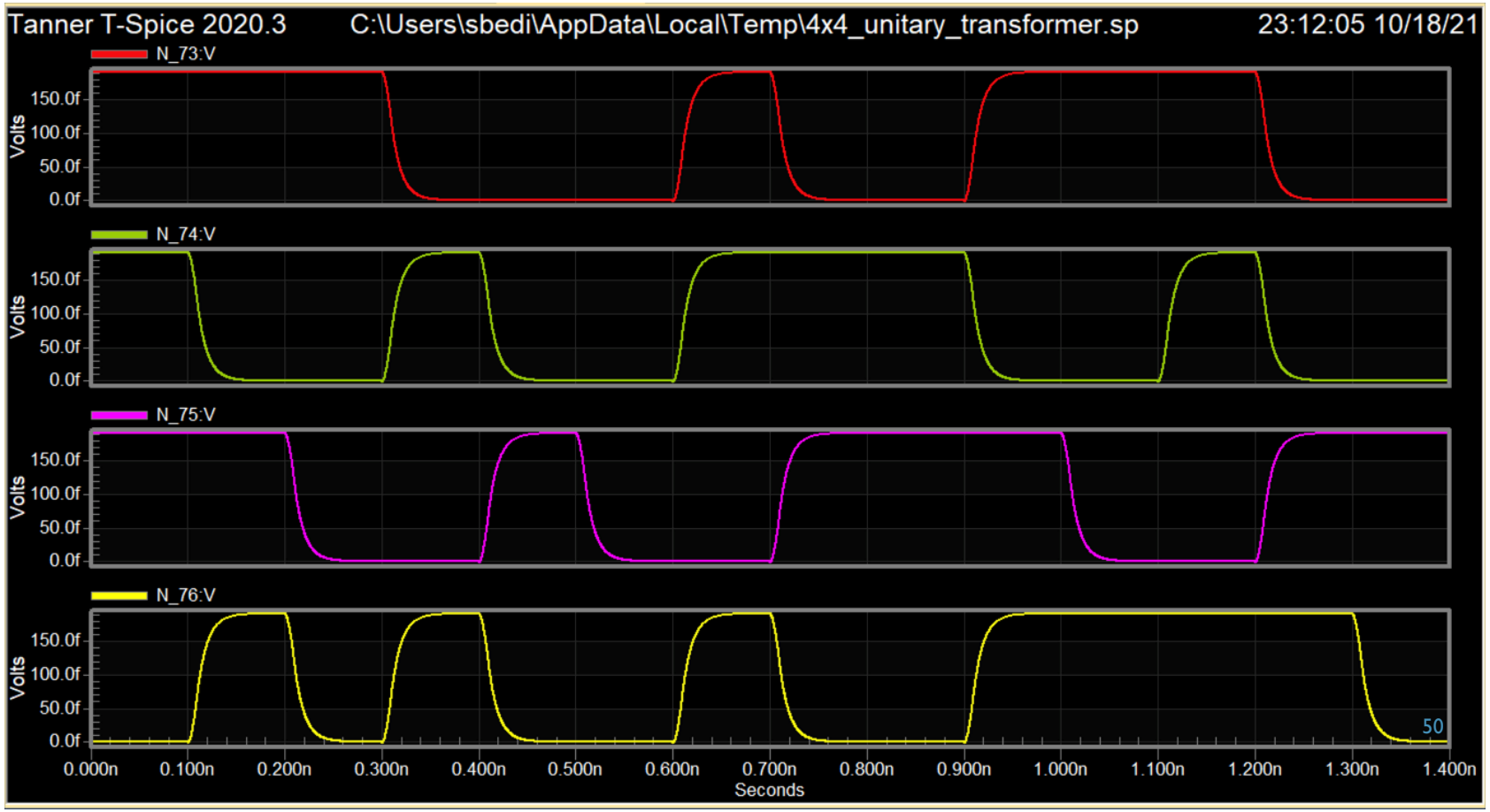
- Create a test-bench and run simulation
- The .SUBCKT has four inputs and four outputs.
- 4 lasers send four different frequency channels 193.1, 193.2, 193.3, 193.4 THz with random bit sequence.
- These random bit sequences are detected at the output using photodiodes.
- Each frequency channel is represented with a separate colour
  - Ch4 [1110001001 1100]
  - Ch3 [1001001110 0100]
  - Ch2 [1100100111 0011]
  - Ch1 [0101001001 1110]



OptiSPICE Plugin – Siemens EDA Tanner Workflow

- View results in Tanner Waveform Viewer

- N_73 = Ch4 [1110001001111100]
- N_74 = Ch3 [1001001111001001]
- N_75 = Ch2 [1100100111100111]
- N_76 = Ch1 [0101001001111110]



PDK Support

- PDKs currently supported/released:
  - Centro Nacional De Microelectronica (CNM) – VLC Photonics PDK
  - Fraunhofer HHI PDK
  - Ligentec PDK
- PDKs support/release in future:
  - Smart Photonics
  - Lionix

THANK YOU

SUPPORT@OPTIWAVE.COM