

Synopsys RSoft Solutions

The Source for Photonic Design Software

Table of Contents

About Synopsys' Optical Solutions Group	2	Photonic System Design Suite	33
Academic Programs	3	OptSim™	34
Photonic Component Design Suite	4	OptSim Circuit	36
Options and Utilities	5	ModeSYS™	38
Passive Device		Professional Services and Programs	40
RSoft CAD Environment™	6	To Learn More and System Requirements	41
BeamPROP™	8		
FullWAVE™	10		
BandSOLVE™	12		
ModePROP™	14		
DiffractMOD™	16		
GratingMOD™	18		
FemSIM™	20		
Active Device			
LaserMOD™	22		
Options and Utilities			
MOST™	24		
LED Utility	26		
Solar Cell Utility™	28		
Multi-Physics Utility™	30		
Tapered Laser Utility™	31		

**30-day evaluations are available upon request.
Please contact rsoft_sales@synopsys.com for
further information.**

About Synopsys' Optical Solutions Group

Synopsys' Optical Solutions Group is one of the world's leading developers of optical design and analysis tools, with CODE V® imaging design software, LightTools® illumination design software, LucidShape® products for automotive lighting, and RSoft™ products for photonic and optical communication design.

Synopsys' RSoft products are leading solutions in photonic design software and serve several industries including optical communication, optoelectronics and semiconductor manufacturing. Within optical communications, RSoft products provide a full range of design, optimization and planning tools. Within the physical layer, RSoft products provide the most extensive collection of award-winning design tools for passive and active optoelectronic components and subsystems. Learn more at <http://optics.synopsys.com>.

History

In May 2012, Synopsys acquired RSoft Design Group, a pioneer in the field of photonic design and simulation software. RSoft released its first software package for the integrated optics industry in 1990. In 2001 RSoft merged with NDTI, a spin off from Telcordia Technologies, and two years later, acquired Artis Srl. RSoft has been committed to meeting the needs for passive and active device design as well as optical communication systems simulation since 1990. Now part of the Optical Solutions Group at Synopsys, the RSoft products have a long and successful history of providing innovative solutions to the most complex optical engineering challenges.

Business Partners

We have established partnerships with both hardware and software companies to broaden the capabilities of our software. Hardware companies such as Luna Technologies have partnered with us to integrate our software tools into test and measurement applications. MathWorks and other software manufacturers have added extended software benefits to the end user.

Online Learning Resources

Learn more about the RSoft products with our white papers and application case studies available at <http://optics.synopsys.com/rsoft/rsoft-product-literature.html>.

RSoft product customers have access to a dedicated website with video tutorials, example project files, usage tips, documentation and training materials. Contact us today for an evaluation of our software and resources.

Academic Programs

As the global leader in photonic design automation software, Synopsys' Optical Solutions Group is committed to support academic research and education. Our academic program provides professors, researchers, and students at several hundred academic institutions all over the world access to RSoft products for the design of photonic components and optical communication systems. This creates an infrastructure in which the next generation of optical engineers can be trained, new ideas can be transformed into reality through advanced research, and the RSoft products are ensured to meet the latest R&D needs through collaborations with leading research groups.

Benefits

- ▶ Available single/multi-user license at a discounted price for research and classroom teaching
- ▶ Collaboration with university research groups to develop advanced simulation features and algorithms
- ▶ Partnership in government funded research programs
- ▶ Commercialization of in-house developed models/software and IP licensing
- ▶ Well-developed course tutorials with simulation examples
- ▶ Demo software with leading textbooks
- ▶ Hundreds of application notes and simulation samples
- ▶ Student scholarships to encourage research of novel modeling and simulation techniques
- ▶ Practical training and internship program
- ▶ Joint research publications
- ▶ Hundreds of published articles, white papers and journals for reference
- ▶ Well represented in standard organizations and industry associations

For more information on our academic programs, please contact Synopsys' Optical Solutions Group at rsoft_sales@synopsys.com.

RSoft Photonic Component Design Suite

RSoft Photonic Component Design Suite

The RSoft Photonic Component Design Suite allows users to design and simulate both passive and active photonic devices for optical communications, optoelectronics, and semiconductor manufacturing.

The Photonic Component Design Suite consists of two design suites: a Passive Device Suite and an Active Device Suite. Each suite includes a CAD environment and simulation engines.

Key Features

- ▶ Highly accurate algorithms allow for rapid virtual prototyping, reducing the need for costly and lengthy physical prototyping, increasing productivity and decreasing time-to-market
- ▶ Assists in the discovery of new products by creating “what if” product scenarios
- ▶ Each algorithm engine shares a common CAD interface; the software can utilize multiple RSoft packages without having to import designs from one software to the next
- ▶ Highly flexible design environment allows virtually any geometry and material profile to be created
- ▶ Extensive output options for many electromagnetic quantities
- ▶ Scripting can be done with any programming language
- ▶ Includes automated parameter scanning via MOST
- ▶ Interfaces with Synopsys' CODE V and LightTools ray-tracing simulators
- ▶ Any RSoft simulator, including FullWAVE, BeamPROP, DiffractMOD, FemSIM, and ModePROP, can easily be used in Sentaurus Workbench as a part of a Sentaurus TCAD project, and Sentaurus TCAD via a bi-directional interface based on native file formats
- ▶ Each simulation engine is licensed separately, allowing users to choose only those that are relevant to their work

PASSIVE DEVICE

RSoft CAD Environment

Layout and control program shared by all RSoft's passive device simulators

BeamPROP

Simulates waveguides, photonic integrated circuits, and fiber applications

FullWAVE

Propagates light in micro- and nano-photonic devices

BandSOLVE

Computes band structures of photonic bandgap devices

ModePROP

Simulates light propagation through photonic devices by eigenmode expansion

DiffractMOD

Simulates diffractive gratings, semiconductor surface gratings, and metrology applications

GratingMOD

Provides the response of optical gratings and fiber Bragg gratings

FemSIM

Calculates transverse and cavity modes for arbitrary structures

ACTIVE DEVICE

LaserMOD

Simulates semiconductor-based lasers, detectors, and modulators

Options and Utilities

The RSoft Options and Utilities extend the capabilities of the Photonic Component Design Suite to provide a complete simulation solution. These tools provide additional simulation options and can be used to combine multiple tools to study advanced application areas.

Key Features

- ▶ Provides an easy and simple method to incorporate additional simulation capabilities with RSoft's simulation tools
- ▶ Combines the strengths of multiple simulation tools to meet the needs of specific application areas
- ▶ Each simulation engine is licensed separately, allowing users to choose only those that are relevant to their work
- ▶ Certain options and utilities are included in a limited form with some of the RSoft simulation tools. See product descriptions for complete licensing details

OPTIONS AND UTILITIES

MOST

An iterative design and optimization utility for all of the RSoft passive device design tools

LED Utility

Simulates the optics of novel LED structures

Solar Cell Utility

Provides an optical and electronic simulation solution for solar cells

Multi-Physics Utility

Extends passive device simulator capabilities to include index perturbations from physical effects

Tapered Laser Utility

Models tapered laser cavities

RSoft CAD Environment

The RSoft CAD Environment is the core program of the RSoft Passive Device Suite, and allows researchers and engineers to create systems for the design of waveguide devices, optical circuits, and other photonic devices. It acts as a control program for the RSoft passive device modules, including BeamPROP, FullWAVE, BandSOLVE, ModePROP, DiffractMOD, GratingMOD, and FemSIM, and defines the important input required by these programs: the material properties and structural geometry of the device to be studied.

Benefits

- ▶ Highly flexible design environment allows virtually any geometry to be created
- ▶ Included with each of the RSoft passive component simulation tools
- ▶ Provides a unified platform for RSoft passive component simulation tools; designs do not need to be imported from one software package to another to use different simulation algorithms
- ▶ Easy to use, streamlined user interface that allows fine control over device layout and simulation

Layout Capabilities

The RSoft CAD Environment has been designed from the ground up to accommodate the special needs of photonic devices and circuits. Fundamental objects such as straight, tapered, and curved components, lenses, and polygons can easily be selected from the toolbar and graphically added to the circuit using the mouse. In addition to standard objects, the CAD allows for the creation of customized components using mathematical equations or data files. Component positions may be specified directly, either absolutely or through relative offsets with respect to any other component. At any time, one or several components may be selected and moved, scaled, deleted, or reinserted. This unique design approach provides an extremely flexible system in which the desired logical arrangement can be maintained.

Object-Oriented Design

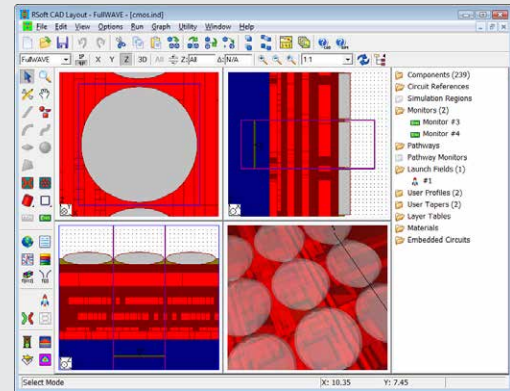
Each individual component has its own set of properties that can be accessed with a right click of the mouse. Parameters include shape information and optical properties such as refractive index profile type and value. This unique object-oriented input model is extremely flexible. Furthermore, each parameter of a component (e.g., position coordinates, width, index) can be specified by an arithmetic expression involving user-defined variables, rather than simply being a constant number. This allows an entire design to be easily modified by using formulas to define each component's angle, or the entire circuit can be modified by simply changing the value of a single variable without having to edit multiple parts of the structure.

Automated Parameter Scanning

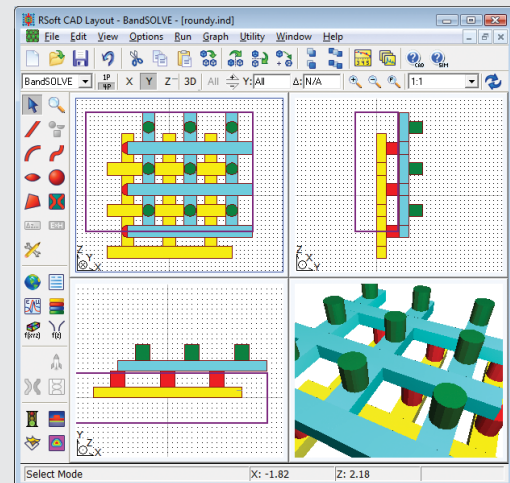
The RSoft MOST Utility automates the tedious task of parameter scanning to find desired device performance. Any quantity produced by an RSoft tool can be the target of a scan or optimization. See page 24 for more details.

Features

- ▶ 3D editing options allow the structure to be viewed along the X, Y, and Z axis
- ▶ A multi-pane mode where the X, Y, Z, and rotatable 3D views are shown at once
- ▶ Object-oriented design environment (see previous page)
- ▶ Hierarchical layout allows arbitrarily complicated structures to be built from smaller components
- ▶ Arbitrary material profiles can be incorporated via expressions or data files
- ▶ Mask files in CIF, DXF, and GDS-II formats can be directly imported into the CAD interface. Design files can be exported in both DXF and GDS-II files for mask fabrication
- ▶ Structures can be directly imported from Sentaurus Workbench (SDE or Sentaurus Process) using native file formats
- ▶ Includes layout utilities for common periodic, grating, and AWG structures
- ▶ Dynamically sized periodic arrays of objects
- ▶ Material library with built-in materials and support for user-defined materials
- ▶ Includes WinPLOT, RSoft's technical graphing program
- ▶ Includes DataBROWSER which allows users to quickly browse and view results
- ▶ Several utilities are included for custom pre- and post-processing capabilities including interfaces with Synopsys CODE V and LightTools software



Multi-pane view of 3D CMOS design in CAD showing views along the X, Y, and Z axes as well as 3D view



Multi-pane view of 3D PBG in CAD

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

BeamPROP

BeamPROP is the industry-leading design tool based on the Beam Propagation Method (BPM) for the design and simulation of integrated and fiber-optic waveguide devices and circuits. The software has been commercially available since 1994, and is in use by leading researchers and development engineers in both university and industrial environments worldwide.

Benefits

- ▶ Industry-proven BPM algorithm for fast and accurate device design
- ▶ Built-in advanced Arrayed Waveguide Grating (AWG) utility for simplifying router and demultiplexer design
- ▶ Advanced capabilities allow for the simulation of complicated devices
- ▶ Fully integrated into the RSoft CAD Environment (page 6)

Applications

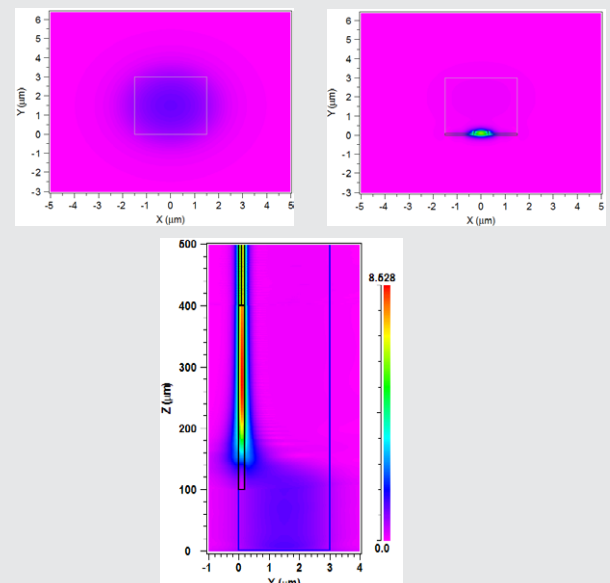
BeamPROP has applications in a wide range of integrated and fiber-optic devices including, but not limited to:

- ▶ WDM devices such as AWG routers
- ▶ Silicon photonics
- ▶ Switches, such as directional coupler-based or digital-y type
- ▶ Modulators, such as Mach-Zehnder type
- ▶ Multimode interference devices
- ▶ Passive 1 x N or N x N splitters
- ▶ Laser-structure transverse mode analysis
- ▶ Standard and specialty fiber design
- ▶ Gratings
- ▶ Sensor structures

Featured Application

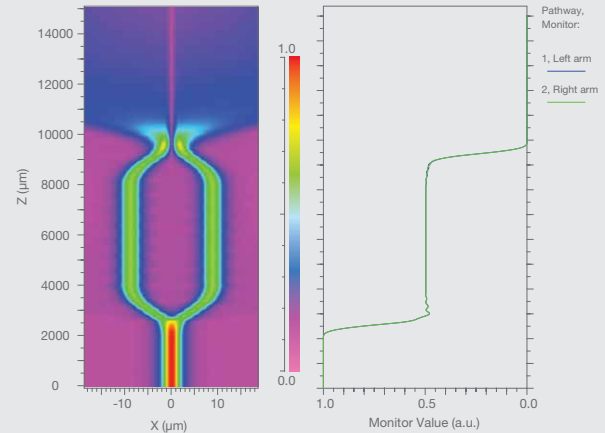
BeamPROP optimized results for spot size converter (SSC) design, with $<0.22\text{dB}$ fiber-to-waveguide coupling loss with a $300\mu\text{m}$ taper length and 80nm tip width. BeamPROP provides rigorous, fast simulations of light propagation in the taper structure. FDTD is too slow due to large taper size. (BeamPROP is $\sim 1300\times$ faster than FDTD in simulating this SSC.) Eigenmode expansion requires modes to be computed at a large number of junctions.

See the application note at
https://optics.synopsys.com/rsoft/pdfs/RSoftApp_sip_Spot_Size_Converter.pdf

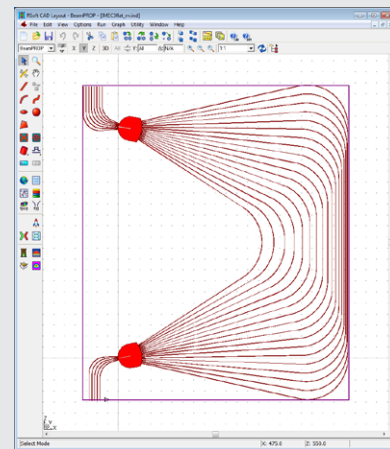


Features

- ▶ Superior, robust and efficient results via an implementation of the Beam Propagation Method (BPM) based on an implicit finite-difference scheme
- ▶ 2D and 3D simulation capabilities
- ▶ Increased performance through multi-threading on computers with multiple cores/CPUs
- ▶ Non-uniform mesh
- ▶ Anisotropic and non-linear materials
- ▶ Fully integrated with Multi-Physics Utility (page 30)
- ▶ Polarization effects and coupling via a full-vectorial BPM implementation
- ▶ Wide-angle propagation can be improved by multistep Padé approximation techniques, a dynamic reference wave number, and conformal index mapping of bends to allow for accurate and efficient off-axis propagation
- ▶ Several boundary condition types including PML
- ▶ Bidirectional BPM formulation for considering reflection along the propagation direction to be considered
- ▶ Two BPM-based mode-solvers for the computation of modal propagation constants and profiles for both guided and radiation modes for 2D and 3D geometries
- ▶ Comprehensive measurement tools to compute 1D/2D/3D data slices of field, power, loss, absorption, etc.
- ▶ Automated parametric studies and design optimization using MOST (page 24)
- ▶ Fully integrated into Sentaurus TCAD via a bi-directional interface that uses native file formats
- ▶ Includes the AWG Utility, which automates the design of AWG (Array Waveguide Grating) devices, including self-consistent 2D, 2D EIM (Effective Index Method) and 3D simulation of AWGs based on any material system



BeamPROP simulation of a Mach-Zehnder modulator operating completely out of phase. The power in each arm is shown on the right



The AWG Utility, included with BeamPROP, produces an AWG design and mask layout based on user-specified parameters such as channel spacing, center wavelength, number of input/output ports, materials, polarization, and waveguide cross-section.

See the application note at
https://optics.synopsys.com/rsoft/pdfs/RSoftApp_C_sipAWG.pdf

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

FullWAVE FDTD Simulation

FullWAVE simulation tool employs the finite-difference time-domain (FDTD) method to perform a full-vector simulation of photonic structures. It is a highly sophisticated tool for studying the propagation of light in a wide variety of photonic structures, including integrated and fiber-optic waveguide devices, as well as circuits and nanophotonic devices such as photonic crystals. FullWAVE's award-winning, innovative design and feature set has made it the market leader among optical device simulation tools.

Benefits

- ▶ Cutting-edge implementation of mature FDTD algorithm allows for a wide range of simulation and analysis capabilities
- ▶ Advanced capabilities allow for clustered simulation environment for massive computational increases in speed and efficiency
- ▶ Many options have automatic settings with built-in expertise to streamline the design process
- ▶ Fully integrated into the RSoft CAD Environment (page 6)

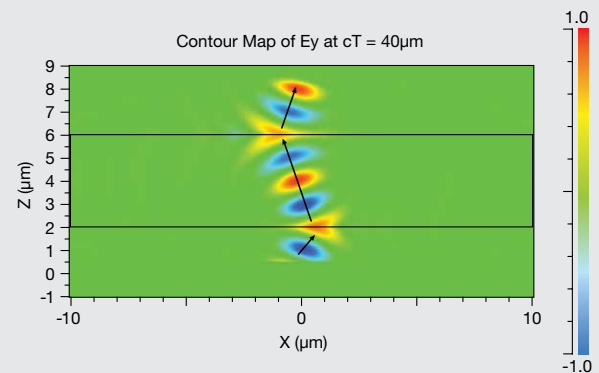
Applications

FullWAVE has applications in a wide range of integrated and nano-optic devices including, but not limited to:

- ▶ WDM devices such as ring resonators
- ▶ Photonic bandgap circuits and applications
- ▶ Silicon photonics
- ▶ Grating structures, surface normal gratings, and other diffractive structures
- ▶ Cavity computations and extractions
- ▶ Nano- and micro-lithography
- ▶ Biophotonics
- ▶ Light scattering
- ▶ Metrology
- ▶ LED/OLED extraction analysis
- ▶ Sensor and bio-sensor designs
- ▶ Plasmon propagation effects
- ▶ Surface plasmons
- ▶ Negative refractive index materials

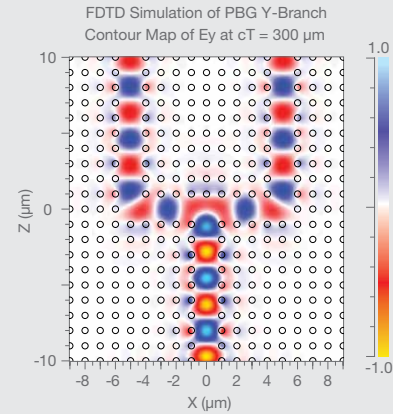
Featured Application

Demonstration of negative index refraction with the propagation of a beam through a left-handed material bounded by air.

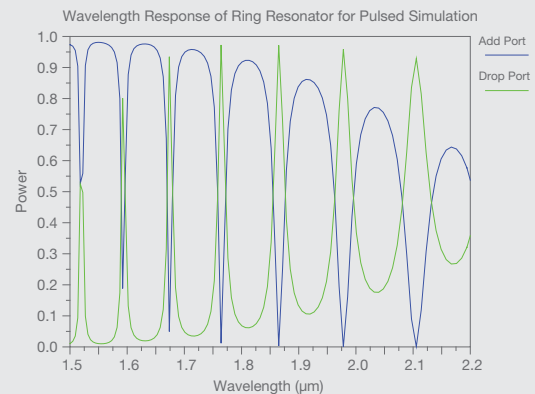
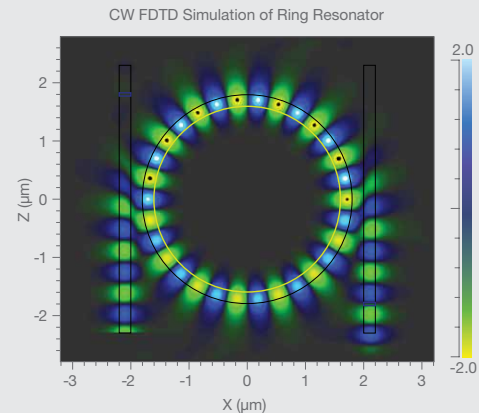


Features

- ▶ Many options have automatic settings with built-in expertise to streamline the design process
- ▶ Advanced and robust FDTD implementation allowing for full-vector field solutions in arbitrary structures and materials
- ▶ 2D, radial, and 3D simulation capabilities
- ▶ Non-uniform mesh, including robust grid control based on local material properties
- ▶ Full control of dispersion, non-linear (χ^2 and χ^3), and anisotropic effects including arbitrary crystal axis orientation
- ▶ Frequency-dependent saturable gain model
- ▶ Dispersion-fitting utility to easily create dispersive models from measured data
- ▶ Includes advanced Perfectly Matched Layer (PML), PEC, periodic, and symmetric/anti-symmetric boundary conditions
- ▶ Advanced excitation options for multiple launch fields, each with different spatial and temporal characteristics such as position, wavelength, direction, polarization, and temporal excitation. Point sources and white light sources are also available
- ▶ Total-field/scattered-field formulation for scattering problems
- ▶ A wide range of analysis and monitoring features to measure common electromagnetic quantities such as field profiles, power flux, energy densities, overlap integrals, far fields, and the Poynting Vector. Additionally, both FFT and DFT options are included for frequency analysis
- ▶ Dynamic field display during simulation and ability to create movies of field evolution
- ▶ Includes Q-Finder, a utility that automates the search for cavity modes and Q-factors
- ▶ Calculate polarimetric BSDF (Bidirectional Scattering Distribution Function) files
- ▶ Includes RSoft BSDF User-Defined Optical Property (UDOP), which can be used with Synopsys' LightTools software. The UDOP supports polarization, exact diffractive angular data, and support for the full AOI angle range (0-360)
- ▶ Simulate the reflection/transmission from an infinite structure for a non-infinite source (i.e., not a plane-wave) using BSDF. Using the Ray-Tracing Interface, these field files can be used with Synopsys' CODE V software
- ▶ Automated parametric studies and design optimization using MOST (page 24)
- ▶ Fully integrated into Sentaurus TCAD via a bi-directional interface that uses native file formats
- ▶ Increased performance through parallel processing via multi-CPU/core machines and/or clustering across a network of computers. Contact Synopsys' Optical Solutions Group for licensing policies regarding this feature
- ▶ FullWAVE is a native 64-bit application that takes advantage of modern 64-bit CPUs that support additional system memory (RAM)



FullWAVE CW simulation of photonic bandgap y-branch structure



Top: CW response of ring resonator run at a wavelength resonance of 1.593 μm

Bottom: Wavelength response of a pulsed simulation of the same resonator

BandSOLVE

BandSOLVE is the first commercially available design tool to automate and simplify the modeling and calculation of photonic band structures for all photonic crystal (PC) devices. The BandSOLVE simulation engine employs the Plane Wave Expansion (PWE) algorithm to perform band computations, and also provides a graphical display of the electromagnetic fields and other quantities of interest for further analysis.

Benefits

- ▶ Advanced implementation of PWE and FDTD (for FullWAVE users only) algorithms allows for a wide range of simulation and analysis capabilities for different types of PBG devices and materials
- ▶ Built-in array layout utility as well as layout hierarchy offers a convenient way to create both standard and custom PBG structures
- ▶ A large number of real application examples
- ▶ Fully integrated into the RSoft CAD Environment (page 6)

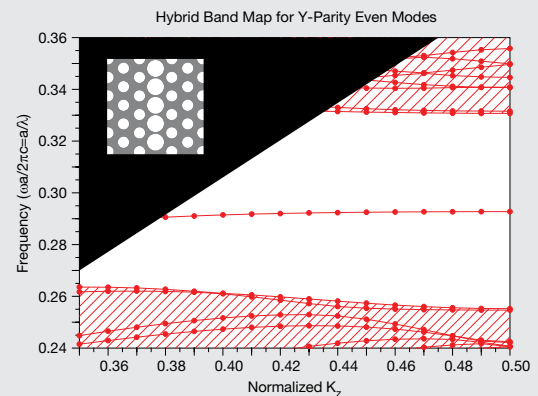
Applications

BandSOLVE can be used to optimize the band structure of new photonic crystal geometries before fabricating the device and to determine the performance of existing components. BandSOLVE can be applied to a wide range of PC components, including but not limiting to:

- ▶ 2D and 3D PC slab and waveguides
- ▶ 2D and 3D cavity problems
- ▶ Photonic crystal fibers, both band-gap guiding and conventional guiding
- ▶ Defect modes of non-strictly periodic structures
- ▶ Metallic and anisotropic structures

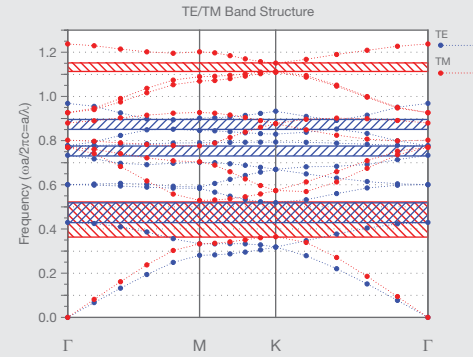
Featured Application

Band diagram for even modes of a waveguide in a lattice of air holes in a photonic crystal slab as computed by a 3D BandSOLVE simulation. The black area represents the leaky mode region, the shaded red regions represent the slab modes, and the red line represents guided modes in the waveguide. The waveguide was formed by enlarging one row of holes as shown.

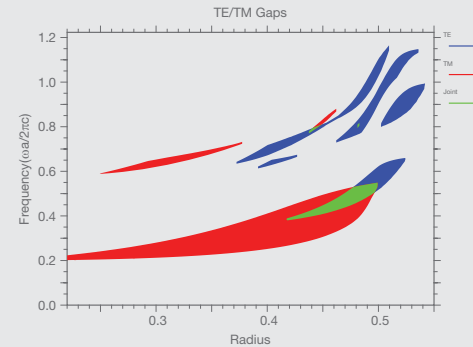


Features

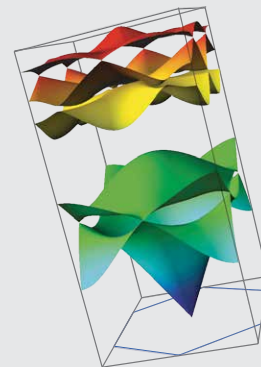
- ▶ Employs a very efficient and robust Plane Wave Expansion (PWE) algorithm that can solve for the band gaps of most 1D, 2D, and 3D PBG devices
- ▶ Includes several advanced simulation features for more efficient, fast band computations, such as inversion symmetry, mode seeding, and parity for 3D calculations
- ▶ Includes a Finite-Difference Time-Domain (FDTD) engine (for FullWAVE users only) for situations in which the PWE algorithm is not applicable, such as metallic and non-linear systems
- ▶ Employs complete and powerful post-processing tools for the calculation of a wide range of data and graphs. BandSOLVE's analysis features include:
 - Band gaps, band maps, and gap maps
 - Mode computation including Bloch and defect modes
 - Wide range of measurements such as effective and group index, group velocity, and dispersion
 - Equi-frequency plots for analysis of the entire Brillouin zone
 - Light cone filters for photonic crystal slab applications
 - Fixed-frequency analysis to incorporate material dispersion



Band structure for a 2D hexagonal lattice of air holes



Band gaps for a 2D hexagonal lattice of air holes vs. hole radius



Band surfaces for a 2D hexagonal lattice of air holes

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

ModePROP

ModePROP is an Eigenmode expansion propagation tool that accounts for both forward and backward propagation and radiation modes. It provides a rigorous steady-state solution to Maxwell's equations that is based on the highly-stable Modal Transmission Line Theory. A full array of analysis and simulation features make this tool flexible and easy to use.

Benefits

- ▶ Rigorous full-vector analysis
- ▶ Solves for both forward and backward traveling modes
- ▶ Fully integrated into the RSoft CAD Environment (page 6)

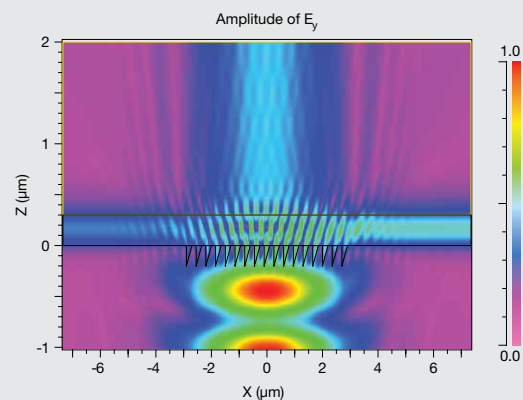
Applications

ModePROP has applications including, but not limited to:

- ▶ Waveguide/fiber-based systems
- ▶ Surface-normal grating couplers
- ▶ Plasmonic devices
- ▶ Sensors
- ▶ Filters
- ▶ Mode converters
- ▶ Photonic bandgap
- ▶ Computing coupling efficiency

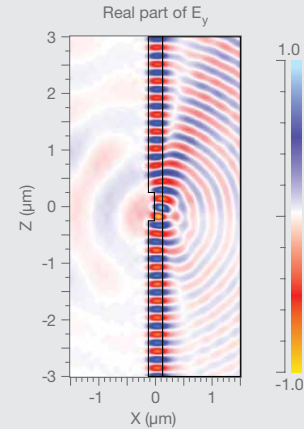
Featured Application

ModePROP simulation results of a blazed finite surface grating. An incident Gaussian beam is coupled into a waveguide by a surface grating.

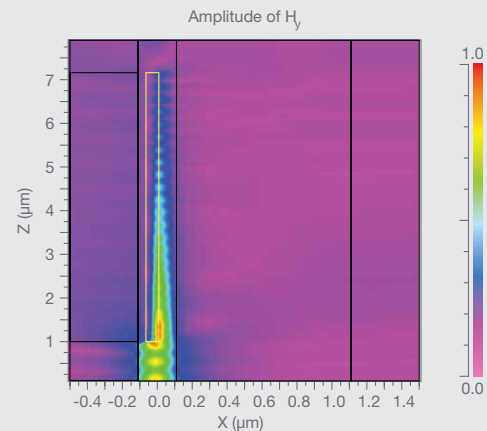


Features

- ▶ Full-vectorial analysis for both Cartesian and cylindrical (azimuthally symmetric) structures in 2D and 3D
- ▶ Modal Transmission Line (MTL) framework to ensure that the simulation is unconditionally stable
- ▶ Increased performance through multi-threading and GPU acceleration on computers with multiple cores/CPU and high-end graphics cards
- ▶ Accounts for reflections
- ▶ User-defined initial field
- ▶ Accommodates complex index for lossy materials and high index contrast profiles
- ▶ Robust meshing scheme which conforms to the structure
- ▶ PML boundary conditions
- ▶ Output information includes transmission/reflection of individual modes as well as total values, and the Poynting Vector
- ▶ Sophisticated output options allow user to calculate and display field profiles and other electro-magnetic quantities at any position
- ▶ Automated parametric studies and design optimization using MOST (page 24)



Simulation results that show the field scattered by an air groove



Simulated field within a surface plasmon based interferometer that is operating out of phase

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

DiffractMOD

DiffractMOD is a design and simulation tool for diffractive optical structures such as diffractive optical elements, subwavelength periodic structures, and photonic bandgap crystals. It is based on the Rigorous Coupled Wave Analysis (RCWA) technique that has been implemented using advanced algorithms including fast Fourier factorization and generalized transmission line formulation. Already a market leader, the tool has extensive applications in a broad range of areas including semiconductor manufacturing and wave optics.

Benefits

- ▶ Incorporates advanced algorithm options that extend the basic RCWA technique to improve its robustness, efficiency, and user friendliness
- ▶ Fully integrated into the RSoft CAD Environment (page 6)

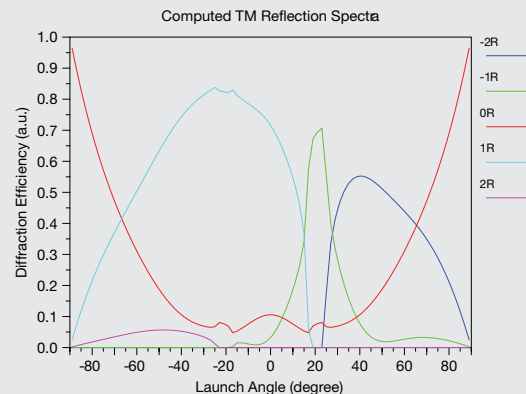
Applications

DiffractMOD can handle complicated periodic structures containing both dielectric and metallic components with lossy or dispersive materials. It has application to a wide range of devices including, but not limited to:

- ▶ Waveguide resonance gratings
- ▶ Diffractive Optical Elements (DOEs)
- ▶ Surface relief and volume index gratings
- ▶ Wavelength filters
- ▶ LED/OLED extraction analysis
- ▶ Optical metrology
- ▶ Nano-lithography
- ▶ Polarization sensitive devices
- ▶ Artificial dielectric coatings
- ▶ Photovoltaic systems
- ▶ 3D displays
- ▶ Optical interconnections
- ▶ Optical data storage
- ▶ Spectroscopy

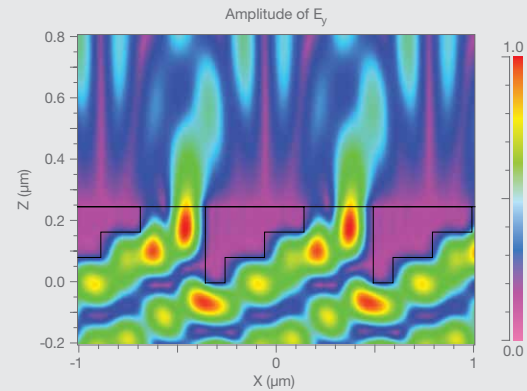
Featured Application

Computed spectra for TM reflected diffraction orders for a 2D metallic grating.

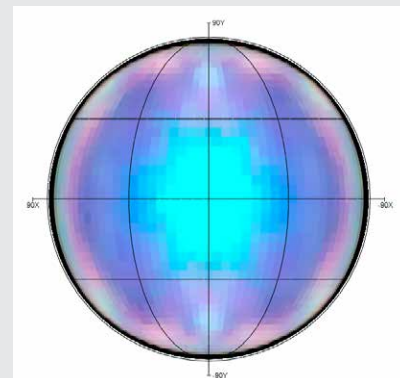
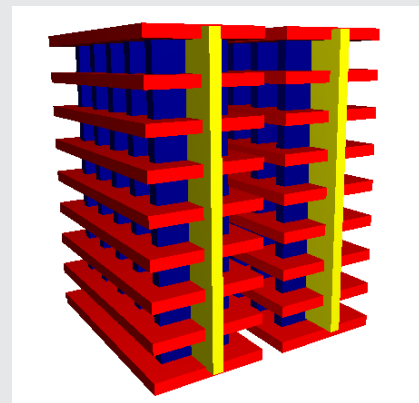


Features

- ▶ Advanced algorithm options are used to improve convergence
- ▶ Modal Transmission Line (MTL) framework to ensure that the simulation is unconditionally stable
- ▶ Full vector simulations for both 2D and 3D. Additionally, conical incidence is allowed
- ▶ An inverse rule is used to improve the convergence of TM fields. For 3D simulation, DiffractMOD can choose appropriate algorithms depending on structures
- ▶ Increased performance through multi-threading and GPU acceleration on computers with multiple cores/CPU's and high-end graphics cards
- ▶ Account for material dispersion and complex refractive index for metals
- ▶ Calculate, display, and output spectra of diffraction efficiency for any diffraction order
- ▶ Calculate total reflected power, transmitted power, and absorbed power
- ▶ A wide range of analysis and monitoring features to measure common electromagnetic quantities at any position such as field profiles, power flux, energy densities, overlap integrals, far fields, and the Poynting Vector
- ▶ Spectrums vs. wavelength, angle and polarization for any diffraction efficiency can easily be computed
- ▶ Output common metrology parameters directly
- ▶ Calculate polarimetric BSDF (Bidirectional Scattering Distribution Function) files
- ▶ Includes RSoft BSDF User-Defined Optical Property (UDOP), which can be used with Synopsys' LightTools software. The UDOP supports polarization, exact diffractive angular data, and support for the full AOI angle range (0-360)
- ▶ Simulate the reflection/transmission from an infinite structure for a finite optical beam (i.e., not a plane-wave) using BSDF. Using the Ray-Tracing Interface, these field files can be used with Synopsys' CODE V software



Field profile of metallic grating structure



Nano-patterned photonic structure modeled in RSoft CAD (top) and reflected angular luminance calculated by LightTools (bottom)

See application note at
https://optics.synopsys.com/rsoft/pdfs/RSoftApp_Nano-Patt Photonic Structure.pdf

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

GratingMOD

GratingMOD is a general design tool for analyzing and synthesizing complicated grating profiles in optical fibers and integrated waveguide circuits for a wide variety of photonic applications. The software is based on the Coupled Mode Theory (CMT) algorithm for fast simulation as well as sophisticated multiple mode algorithms for advanced applications. GratingMOD also provides a general platform for simulation of various coupling mechanisms.

Benefits

- ▶ Incorporates advanced algorithms to improve its robustness, efficiency, and user friendliness
- ▶ Fully integrated into the RSoft CAD Environment (page 6)

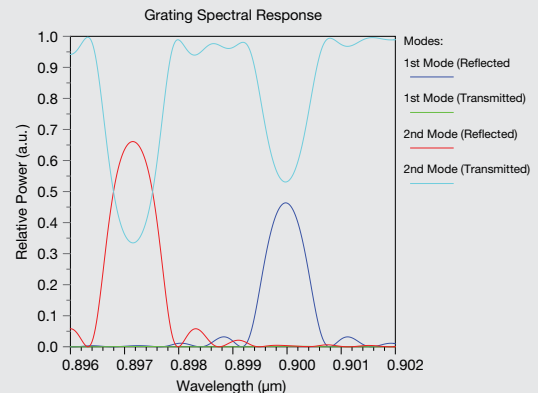
Applications

GratingMOD can handle various grating structures for both fiber and integrated waveguides. It has applications to a wide range of integrated and fiber-optic devices including, but not limited to:

- ▶ Dispersion compensation fiber Bragg grating
- ▶ Multiplexing/demultiplexing
- ▶ Add/drop filtering
- ▶ Gain equalization in optical amplifiers
- ▶ Grating-assisted couplers
- ▶ Long-period grating sensors

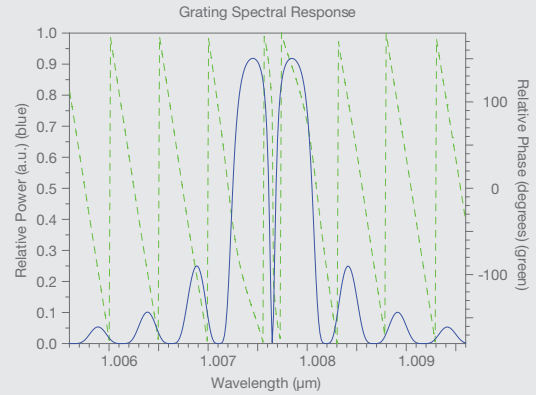
Featured Application

Results for multimode simulation of a grating-assisted coupler. Spectra are shown for both forward and backward propagation for both modes in the structure.

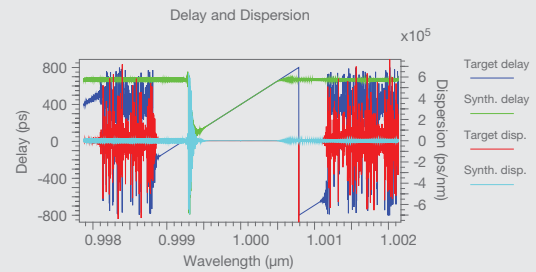
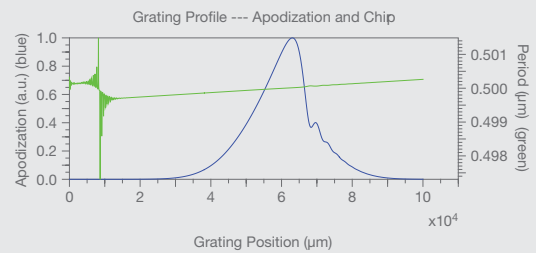


Features

- ▶ Bragg condition searching to find both the period from the specified modes and the modes from a specified period
- ▶ Sophisticated orthogonality relations for both lossless and lossy waveguide are included
- ▶ Optimal modes are used to reduce error
- ▶ Analytical mode calculations can be used when applicable
- ▶ An arbitrary number of gratings at arbitrary positions in both 2D and 3D structures can be used to study coupling mechanisms. Coupling mechanism includes fiber core coupling, fiber core to cladding coupling, long period fibers, as well as side coupling and vertical coupling for integrated circuits
- ▶ Multi-mode grating systems can be analyzed via a multi-mode CMT implementation
- ▶ An advanced synthesis tool utilizes a state-of-the-art synthesis technique to solve the 'inverse' problem
- ▶ Both waveguide and material dispersion can be included
- ▶ Transmitted and reflected spectra for each mode can be determined
- ▶ Calculation of phase, dispersion, and time delay
- ▶ Generation of mode, apodization, chirp, and grating profiles
- ▶ Automated calculation of band width for primary order reflection
- ▶ Spectrum analysis and Bragg condition analysis



Simulation results showing the phase and amplitude



Synthesis results of a grating with constant dispersion compensation

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

FemSIM

FemSIM is a generalized mode solver based on the Finite Element Method (FEM) that can calculate any number of transverse or cavity modes of an arbitrary structure on a non-uniform mesh. FemSIM employs a full-vector implementation and has been enhanced with many features to compute complex modes. The tool is flexible and extendable to a wide range of problems such as high index contrast, plasmonic, and photonic bandgap based waveguides.

Benefits

- ▶ Advanced implementation of the FEM algorithm allows for a wide range of simulation and analysis capabilities for different types of devices
- ▶ Can be used in conjunction with other RSoft tools to solve for modes and then propagate them through a device
- ▶ Fully integrated into the RSoft CAD Environment (page 6)

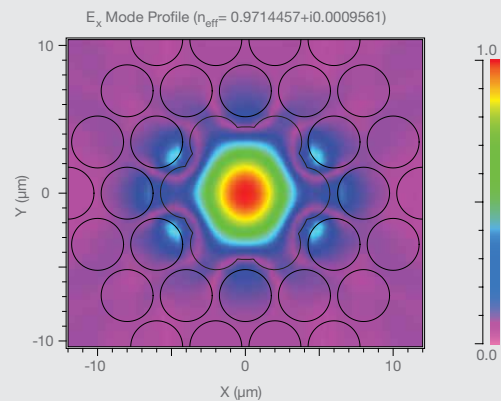
Applications

FemSIM has applications for mode solving to a wide range of integrated and nano-optic devices including, but not limited to:

- ▶ Structures with arbitrary profiles, including those with curved or uncommon shapes
- ▶ Structures with high index contrast and/or small feature sizes
- ▶ Air or solid core photonic fibers
- ▶ Lossy structures
- ▶ Silicon-based devices such as SOIs
- ▶ Polarization rotators
- ▶ Plasmonic waveguides
- ▶ Laser and PBG defect cavities

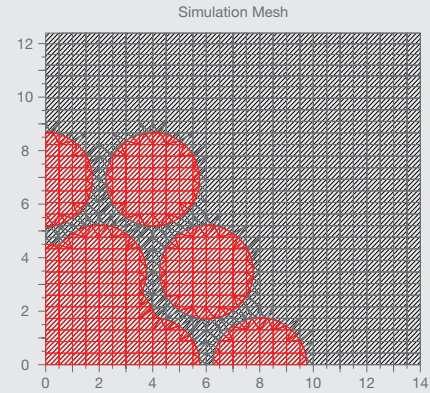
Featured Application

Computed mode profile for an aircore photonic crystal fiber. Symmetric boundary conditions were used in the calculation to provide a speedy solution. The simulation mesh can be seen in the following figures.

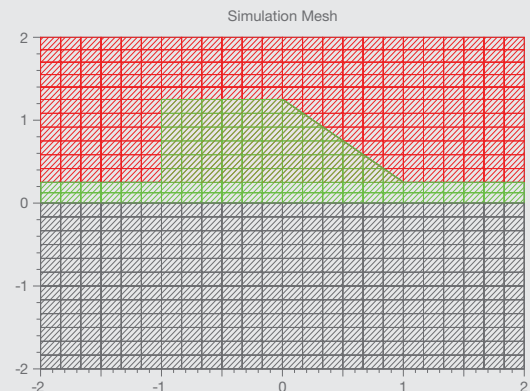
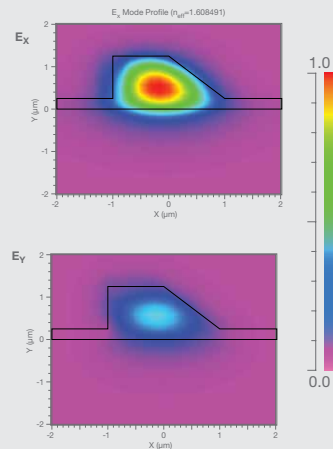


Features

- ▶ Full-vector analysis for both Cartesian (1D, 2D) and cylindrical (azimuthally symmetric) structures
- ▶ Increased performance through multi-threading on computers with multiple cores/CPU's
- ▶ Accommodates complex index for lossy materials and high index contrast profiles
- ▶ Robust meshing scheme that conforms to the index profile using hybrid triangular and rectangular mesh elements
- ▶ First and second order elements used to avoid spurious modes
- ▶ PML and symmetric/anti-symmetric boundary conditions
- ▶ Determination of propagating, leaky, and cavity modes
- ▶ Higher-order modes can be found with minimal additional computational expense
- ▶ Bending modes can be computed
- ▶ Computation of dispersion diagrams
- ▶ Output information includes field profiles, propagation constants, overlap integrals, confinement factors, and diagnostics
- ▶ Automated parametric studies and design optimization using MOST (page 24)



Simulation mesh for aircore photonic crystal fiber



Simulation mesh for a rib waveguide with a tilted facet with a highly hybrid polarization; both E_x and E_y components of the mode are shown

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

LaserMOD

LaserMOD is a photonic device design software tool for simulating the optical, electronic, and thermal properties of semiconductor lasers, modulators, and detectors. LaserMOD can account for a wide variety of important processes, such as thermal flux and carrier transport, within a self-consistent scheme for extremely advanced and thorough semiconductor modeling.

Benefits

- ▶ Versatile, user friendly, parametric CAD interface
- ▶ All simulation modules included in a single package
- ▶ Integrated with RSoft passive device and system tools

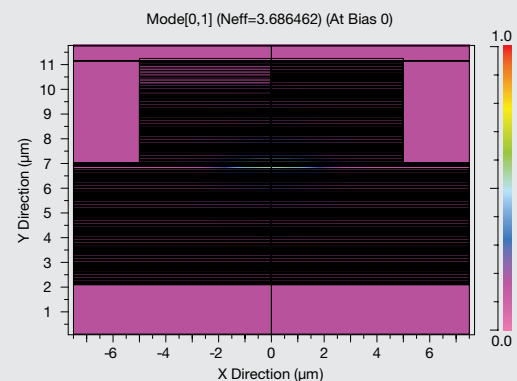
Applications

LaserMOD applications include the following device families:

- ▶ Edge emitting lasers, such as Fabry-Perot (FP), Distributed Feedback (DFB), and Distributed Bragg Reflector (DBR)
- ▶ Cylindrical Vertical Cavity Surface Emitting Lasers (VCSEL)
- ▶ Silicon modulators (electro-absorptive, electro-refractive, and thermo-optic modulators in silicon and other semi-conductor materials)
- ▶ Hybrid and multilevel applications when combined with other tools in the RSoft suite
- ▶ Semiconductor photodetectors including large-area, avalanche, solar-cell, and waveguide types

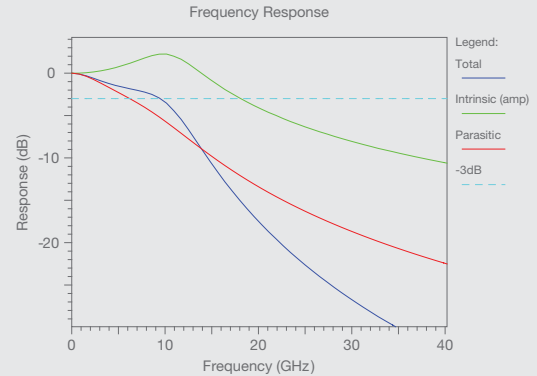
Featured Application

Fundamental cavity mode of an oxide-aperture VCSEL.

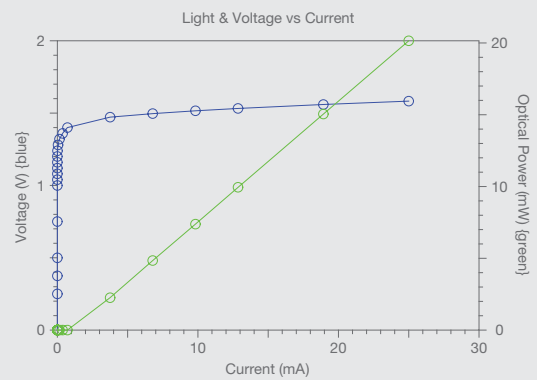


Features

- ▶ 1D, 2D and cylindrical (quasi-3D)
- ▶ Advanced physics based models
- ▶ Self-consistent solution of optics, quantum mechanical gain, and electro-thermal transport
- ▶ Steady-state and time-dependent simulation
- ▶ 8x8 KP band calculation for gain
- ▶ Lookup table base gain model
- ▶ Integrated BPM and FEM mode solvers
- ▶ Integrated mesh generator
- ▶ Extensible material libraries
- ▶ Numerous tutorial examples
- ▶ Standard and custom plot generation
- ▶ Scanning of design parameters



Computed light-current and current-voltage (LIV) characteristics indicating the progress of a steady-state simulation



Frequency response to a small pulse applied at the steady-state operating point. Parasitic effects can be included to account for packaging

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

MOST

MOST*, Multi-variable Optimization and Scanning Tool, is an exciting solution to the critical problem of design optimization for photonic devices. During the research or design cycle, it becomes vital to understand the full parameter space of the system. Acting as an automated driver for the RSoft physics-based simulators, MOST takes the drudgery out of these important operations by streamlining the definition, calculation and analysis of scans and optimizations. Moreover, if you own multiple copies of RSoft products, MOST can automate the distribution of work across your entire network with virtually a single mouse click.

Benefits

- ▶ Automatically scans and optimizes devices with minimal user interaction
- ▶ Automates the design process to take out tedious work
- ▶ A wide range of output and analysis features available through measurement and user-defined metric techniques
- ▶ Fully integrated into the RSoft CAD Environment and with all of the component simulation tools (page 6)

Applications

MOST is applicable to any situation where a range of parameters need to be looked at or optimized including, but not limited to:

- ▶ Perform parameter scans over any design parameter in any number of dimensions
- ▶ Perform single and multiple variable local and global automated optimization
- ▶ Perform global optimization by genetic algorithm
- ▶ Automated distributed computation of scans and some optimizations with all of the passive component simulation tools

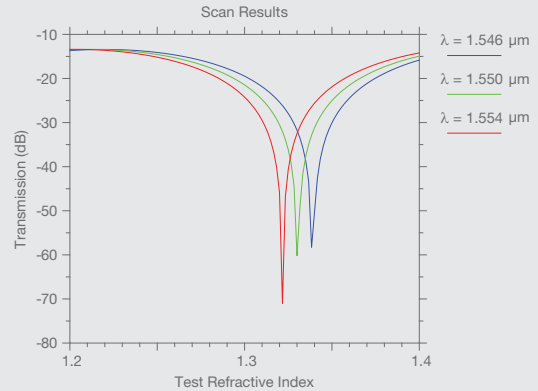
Simulation Technology

MOST provides the most flexible scanning/ optimization environment available today. Measurements are generalized so that any type of data produced by any simulator can be treated in a uniform fashion. Thus, scanning modal effective indices calculated with BeamPROP is identical to scanning diffraction efficiencies calculated with DiffractMOD. In addition, vector and matrix quantities such as reflection spectra or modal profiles are scanned just as easily. Literally, any quantity produced by any RSoft tool can be the target of a scan or optimization.

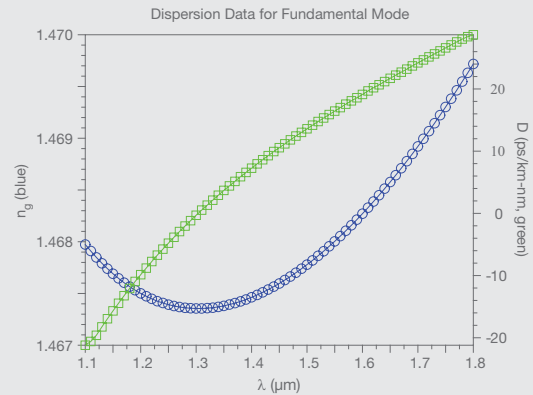
*The scanning portion of MOST is included with all passive device simulation tools; optimization and distributed scanning are licensed separately.

Features

- ▶ Any quantity produced by any RSoft tool can be the target of a scan or optimization
- ▶ Scans and optimizations can be performed over an arbitrary number of parameters
- ▶ Automatic generation of line, contour, and 3D volume plots
- ▶ “Data sliced” plots showing behavior in particular planes of the parameter space
- ▶ Real time convergence plots to track the performance of optimizations
- ▶ Data conveniently accessed and viewed within RSoft’s customized DataBROWSER environment
- ▶ Instantly reprocess existing data in different plot styles
- ▶ Complete data dumps to file of any scanned quantity
- ▶ Several optimization algorithms available for different types of convergence
- ▶ Custom post-processing of simulation output to produce scans/optimizations of any parameter
- ▶ Define new optimization algorithms with MOST through custom modules



ModePROP scan results showing surface plasmon resonance locations for different operating wavelengths as a function of the refractive index of the test material



Computed dispersion parameters for a fiber found using BeamPROP and the scanning/post-processing capabilities of MOST

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

LED Utility

The LED Utility* accurately simulates novel LED structures and all materials involved. The utility simplifies common tasks associated with LED design and aids in the rigorous computation of extraction ratios and radiation patterns. It utilizes the RSoft CAD to describe the geometry and material properties and uses the RSoft flagship simulation tool FullWAVE for modeling the LED. The RSoft CAD interface is a fully parametric, highly flexible user-friendly design environment with 3D editing capabilities to simplify the description of complex LED geometries. The underlying FullWAVE simulation is based on the Finite-Difference Time-Domain (FDTD) algorithm which is an ab-initio approach for solving Maxwell's equations with no inherent approximations that is well suited to accurately model the intricacies of an LED structure.

Benefits

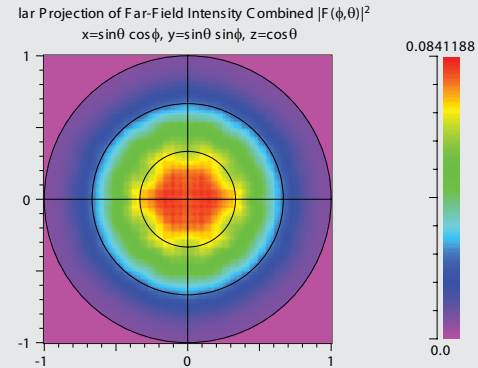
- ▶ Automated optical simulation of incoherent LED structures
- ▶ Fully integrated into the RSoft CAD Environment

Applications

- ▶ LED design
- ▶ LED extraction efficiency optimization
- ▶ Studying effect of patterns on LED operation

Featured Application

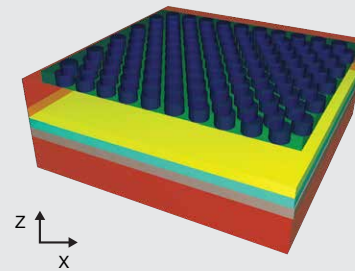
A radiation pattern of a nano-patterned LED structure computed by the LED Utility. This is a combined result for the wavelength range 400 to 700 nm.



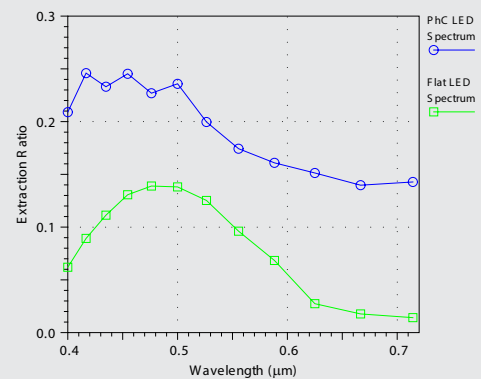
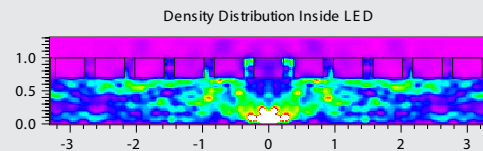
*The LED Utility provides RSoft FullWAVE users the functionality described here. All simulation tools are licensed separately.

Features

- ▶ Arbitrary LED geometry can easily be created in the RSoft CAD
- ▶ Important material properties such as frequency-dependent complex refractive indices can be used
- ▶ Rigorous optical simulation is performed by the RSoft FullWAVE FDTD simulation tool
- ▶ Works with FullWAVE clustering to provide faster results
- ▶ Incorporates an unpolarized incoherent light source
- ▶ Outputs LED extraction efficiency and radiation patterns in addition to the standard FullWAVE output
- ▶ Automated parameter studies and design optimization using MOST (page 24)
- ▶ Convert LED far field to a ray data file for use with Synopsys' LightTools software



A nano-patterned LED structure



Simulation results for a single FullWAVE simulation (top) and extraction efficiency over the wavelength range of 400 to 700 nm

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

Solar Cell Utility

The Solar Cell Utility* provides an optical and electronic simulation solution for solar cell devices. The utility simplifies common tasks associated with solar cell design and aids in the rigorous computation of J-V curves, quantum efficiency spectra, and overall cell efficiency. The basic version of the Solar Cell Utility uses a simple electronic model and operates with one or more RSoft optical simulation tools**. If a rigorous electronic modeling solution is desired, LaserMOD can be used. The Solar Cell Utility LaserMOD option provides a limited license of LaserMOD for this purpose.

Benefits

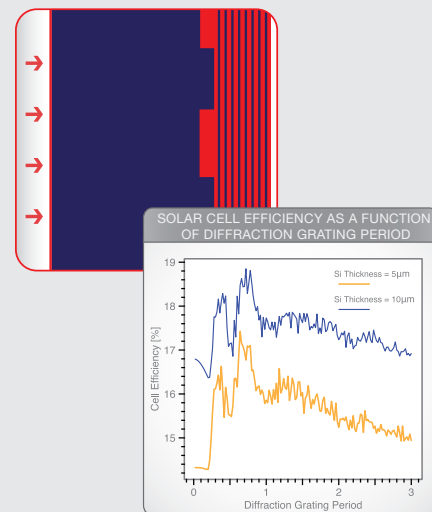
- ▶ Rigorous optical simulation is performed by one of RSoft's passive optical design tools
- ▶ Can use either a simple electronic model or RSoft's rigorous LaserMOD simulation tool
- ▶ Fully integrated into the RSoft CAD Environment (page 6)

Applications

- ▶ Solar cell design
- ▶ Solar cells with diffractive optical elements (DOEs)
- ▶ Solar cells with randomly textured material interfaces
- ▶ Ideal for investigating the electronic nature of solar cells

Featured Application

Schematic of solar cell structure along with solar cell efficiency computed by DiffractMOD as a function of the period of a diffractive optical element within the cell.

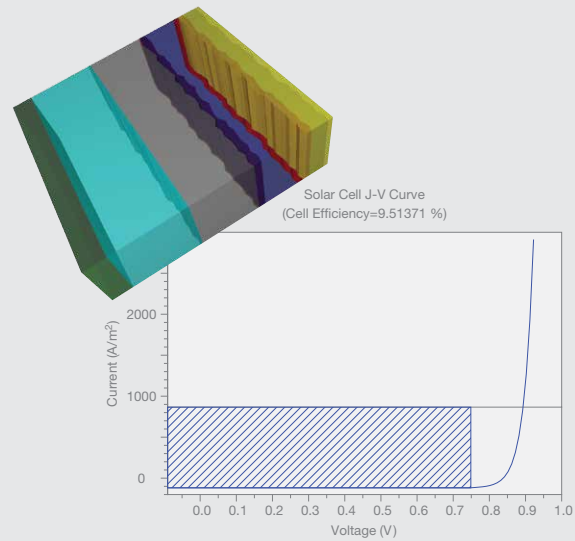


*The Solar Cell Utility provides users of some of the RSoft optical simulation tools the functionality described here. All simulation tools are licensed separately.

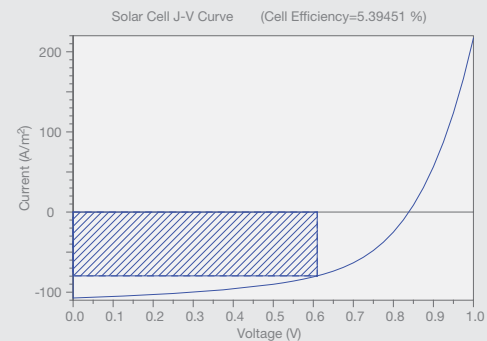
**Consult a Synopsys representative to determine which combinations of products are currently supported.

Features

- ▶ Arbitrary solar cell geometry can easily be created in the RSoft CAD
- ▶ Important material properties such as frequency-dependent complex refractive indexes can be used to correctly model absorptive materials
- ▶ Simple electronic modeling via modified Ideal Diode equation; rigorous modeling via LaserMOD tool
- ▶ Uses the AM1.5 Solar Spectrum as incident spectrum by default; a user-specified spectrum can also be used
- ▶ Direct user control over shadowing, filling-factor, and collection efficiency
- ▶ Accounting of parasitic resistances in both simple and rigorous electronic models
- ▶ Outputs include cell efficiency, J-V curves, and quantum efficiency spectra in addition to the standard output from the simulation tool(s) used (DiffractMOD, FullWAVE, and/or LaserMOD)
- ▶ Automated parametric studies and design optimization using MOST (page 24)



J-V curve for solar cell with randomly textured interfaces computed using Ideal Diode electrical model and FullWAVE



J-V curve for the same solar cell above computed with LaserMOD and FullWAVE

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

Multi-Physics Utility

The Multi-Physics Utility* is designed to be used in conjunction with any of RSoft's passive device simulation tools. It provides a convenient interface from which perturbations of the refractive index profile of a structure may be included in the simulation. These perturbations can be due to advanced physical processes in the material, such as electro-optic effects, thermo-optic effects, stress-optic effects (i.e., strain), and carrier-induced effects. All material parameters needed to describe these effects can be defined in the RSoft Material Library.

Benefits

- ▶ Expands the power of all of RSoft passive device simulation tools
- ▶ Fully integrated into the RSoft CAD Environment (page 6)

Applications

- ▶ Electro-absorptive/electro-refractive modulators
- ▶ Thermo-optic switches
- ▶ Electrically biased modulators
- ▶ Birefringence in waveguides and fibers
- ▶ Stress effects caused by cooling during device fabrication
- ▶ Silicon photonic transport modeling

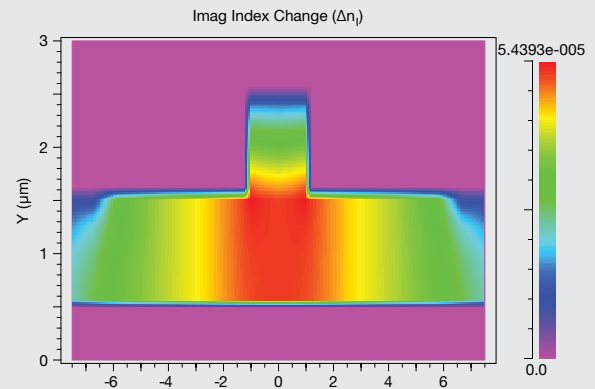
Features

- ▶ Fully integrated with all RSoft passive device simulation tools
- ▶ Leverages the RSoft material library for all model parameters
- ▶ Computes index perturbation by solving Poisson's equation (electro-optic effect), thermal equation (thermo-optic effect), stress-strain equation (stress effect), and by using LaserMOD to model carrier-based effects
- ▶ Automated parametric studies and design optimization using MOST (page 24)
- ▶ Fully integrated into Sentaurus TCAD via a bi-directional interface that uses native file formats
- ▶ Carrier-based effects include fully comprehensive transport and recombination-based models, as well as a large semiconductor- and silicon-based material library

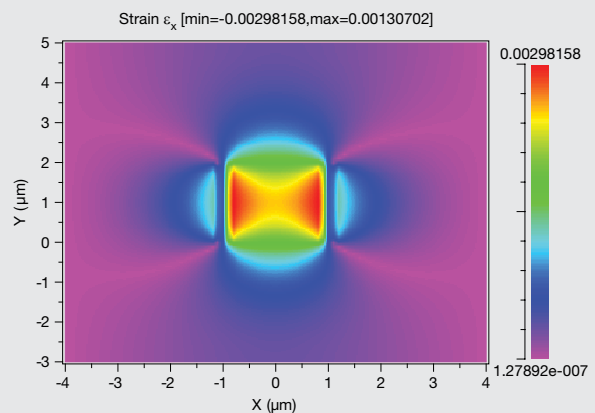
*The basic Multi-Physics Utility with electro-optic and thermo-optic effects is included with all passive device tools; the stress and carrier effects are offered as options that are licensed separately.

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

Featured Applications



Change in refractive index, due to carrier effects, in a silicon ridge waveguide buried in SiO_2



X component of strain in a silicon ridge waveguide buried in SiO_2

Tapered Laser Utility

The Tapered Laser Utility* provides an efficient and accurate design tool for analyzing and optimizing tapered semiconductor laser diodes. It essentially combines, two powerful and mature simulation tools, BeamPROP and LaserMOD, to provide a full 3D simulation of tapered laser diodes. The quasi-3D electrical, quantum mechanical gain and thermal calculations are performed via LaserMOD, whereas the optical field is propagated via BeamPROP.

Benefits

- ▶ Leverages the power of the RSoft BeamPROP and LaserMOD simulation tools for use with tapered semiconductor laser diode applications
- ▶ Fully integrated into the RSoft CAD Environment (page 6)

Applications

- ▶ Tapered laser diode design

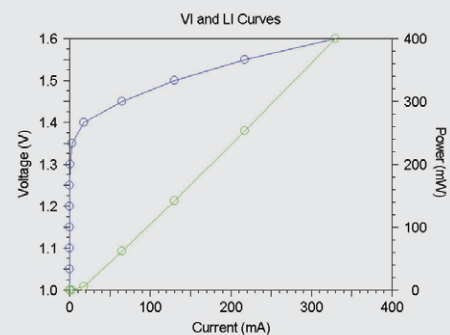
Features

- ▶ Fully integrated with the RSoft Beam-PROP and LaserMOD simulation packages to automatically compute tapered laser characteristics
- ▶ Self-consistent optical, electronic and thermal simulation
- ▶ Extensible material libraries
- ▶ Output information includes L-I curves, I-V curves, spatial field plots, farfields, etc.
- ▶ Capable of simulating physical effects like spatial hole burning, filamentation, over pumping, etc.

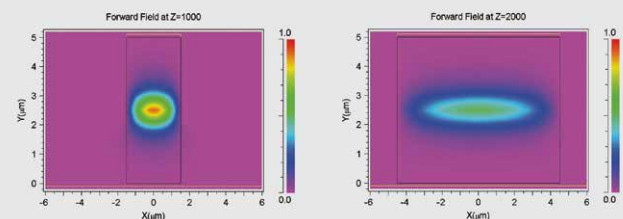
*The Tapered Laser Utility provides users of BeamPROP and LaserMOD the functionality described here. All simulation tools are licensed separately.

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

Featured Applications



Computed light-current and current-voltage characteristics



TL Utility computed stabilized field profiles along different sections of the tapered laser

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RSoft Photonic System Design Suite

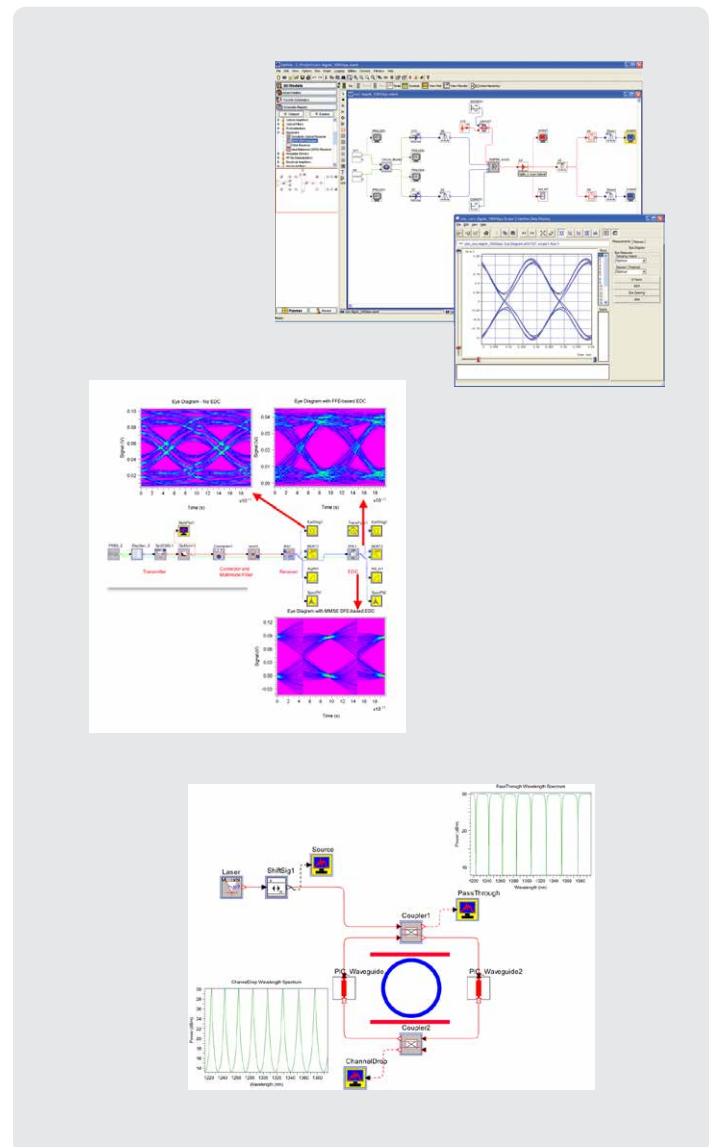
The RSoft Photonic System Design Suite allows users to design and simulate current and next-generation optical communication systems and photonic integrated circuits at the signal-propagation level. The following software packages are part of the suite: OptSim, OptSim Circuit, and ModeSYS. These advanced tools enhance and accelerate user-modeling capabilities and provide real field design scenarios using extensive industry specifications. The customer base includes optical component and equipment manufacturers, system integrators, service providers, as well as government labs and academic institutions. Whether you are interested in maximizing performance, minimizing costs, reducing time to market, or fast prototyping, these tools will become an inseparable partner and the secret of your success.

OptSim and ModeSYS Key Features

- ▶ Enable the user to design and simulate single mode (OptSim) and multimode (ModeSYS) optical communication systems at the signal-propagation level
- ▶ Virtual prototyping reduces the need for costly and lengthy physical prototyping for increased productivity and decreased time to market
- ▶ Optimization of the design for enhanced performance and reduced cost
- ▶ Assist in the discovery and analysis of next generation optical communication systems deploying new modulation formats
- ▶ Interfaces with 3rd-party tools such as MATLAB® and the Luna Optical Vector Analyzer
- ▶ Advanced electrical modeling with embedded Spice engine

OptSim Circuit Key Features

- ▶ Design automation of next-generation photonic integrated circuits (PICs)
- ▶ Modeling of complex bidirectional signal interactions, reflections, multipath interference, and resonance
- ▶ Easy integration with OptSim for PIC performance testing and evaluation at system level



OptSim

OptSim is an award-winning software tool for the design and simulation of optical communication systems at the signal propagation level. With state-of-the-art simulation techniques, an easy-to-use graphical user interface and lab-like measurement instruments, OptSim provides unmatched accuracy and usability. The software has been commercially available since 1998 and is in use by leading engineers in both academic and industrial organizations worldwide.

Benefits

- ▶ Virtual prototyping of optical communication systems for increased productivity and reduced time to market
- ▶ Optimization of the design for enhanced performance and/or reduced cost
- ▶ Cosimulation with RSoft device modeling tools BeamPROP, FullWAVE and GratingMOD
- ▶ Interfaces with 3rd-party tools such as MATLAB® and the Luna Optical Vector Analyzer
- ▶ Advanced electrical modeling with embedded SPICE engine

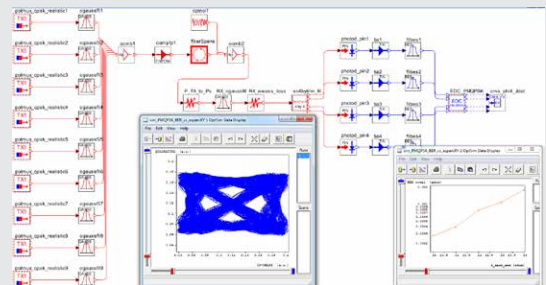
Applications

OptSim is ideally suited for computer-aided design of optical communication systems including, but not limited to:

- ▶ Advanced Modulation Formats, such as D(Q)PSK, Duobinary, PAM, QAM, DMT
- ▶ Coherent Optical Communication Systems, such as PM-QPSK, PM-BPSK, PM-QAM, OFDM
- ▶ Gaussian noise (GN) link emulator for efficient modeling of uncompensated, long-haul coherent systems
- ▶ Data center and automotive optical Interconnects
- ▶ DWDM/CWDM systems with optical amplification, such as EDFA, Raman, SOA, OPA
- ▶ 100G, 400G high-speed Ethernet systems
- ▶ FTTx/PON
- ▶ CATV Digital/Analog
- ▶ Electronic Dispersion Compensation (EDC)
- ▶ Free Space Optics (FSO)
- ▶ Soliton Transmission
- ▶ Interferometric Fiber Optic Gyroscope (I-FOG)

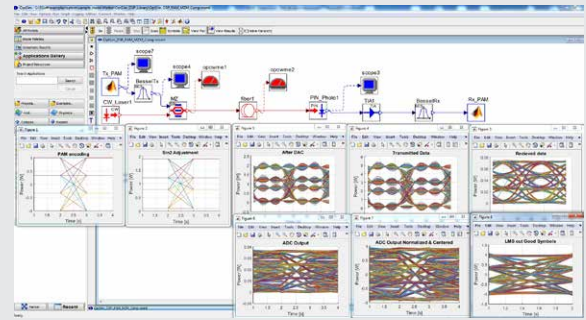
Featured Application

- ▶ Synchronous PoMUX-QPSK system with 9 channels at 107 Gbit/s, 20x100 Km SMF fiber, and a DSP-based digital coherent receiver
- ▶ Direct error counting on 262,144 simulated bits
- ▶ OptSim's unique capability of simulating arbitrarily long bit sequences makes it the tool of choice to design systems where the direct error counting is required to assess the system performance, such as systems using FEC, MLSE, EDC, and DSP-based digital coherent receivers

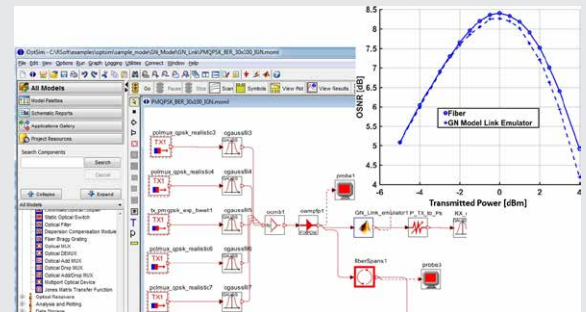


Features

- ▶ Support for multiple parameter-scans-based optimization
- ▶ Only design tool with multiple engines implementing both the Time Domain Split Step and the Frequency Domain Split Step for the most accurate and efficient simulation of any optical link architecture
- ▶ Library of MATLAB-based digital signal processing (DSP) algorithms provide a flexible option for in-line and off-line processing at transmitters and receivers in high bit-rate data transmission systems
- ▶ MATLAB® interface makes it easy to develop custom user models using the m-file language and/or the Simulink® modeling environment
- ▶ Interfaces with laboratory test equipment such as Agilent and Luna to merge simulation with experiment
- ▶ Interfaces with device-level design tools such as BeamPROP and LaserMOD provide a powerful mixed-level design flow for optoelectronic circuits and systems
- ▶ Co-simulation with embedded SPICE engine, and interfaces with EDA tools such as Synopsys HSPICE for a mixed-domain electrical and optical simulation
- ▶ Application Programming Interface (API) for programming languages such as C/C++ for the development of custom user models
- ▶ Best Fit Laser Toolkit™ makes customizing powerful rate-equation laser model parameters to fit desired performance characteristics easily
- ▶ Extensive library of predefined manufacturer components makes it easy to model commercially available devices
- ▶ Intuitive and flexible measurement post-processing graphical interface acts like a virtual laboratory instrument



OptSim project layout of a PAM-4 system. The DSP algorithm spaces PAM-4 levels with an arcsine law so that they are evenly distributed at the output of MZM implementing a cosine law



GN link emulator in OptSim. Layout of a link of over 3000-km, 100G per channel, PM-QPSK system. The GN model based simulation is much faster compared to an equivalent fiber layout with less than 0.2-dB under-estimation of the OSNR.

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

OptSim Circuit

OptSim Circuit is an extension of Synopsys' award-winning fiber optic systems modeling tool, OptSim. It delivers a single framework, engine and sets of models to study systems ranging from long-haul optical communication systems to sub-micron photonic circuits. This enables you to evaluate system-level performance in OptSim of a photonic integrated circuit (PIC) that is designed in OptSim Circuit. It is an ideal platform to study optical systems and photonic circuits that operate with coupling and feedback of different optical and electrical signal paths.

Benefits

- ▶ Innovative tool for the design automation of next-generation photonic integrated circuits (PICs)
- ▶ Reusable user-defined components and compound components
- ▶ MATLAB interface makes it easy to develop custom user models using the m-file language
- ▶ Interfaces to third-party layout tools such as OptoDesigner from Phoenix Software and IPKISS from Luceda Photonics
- ▶ Options for exporting data and for co-simulation with external tools
- ▶ Intuitive graphical user interface
- ▶ Powerful options for data visualization, plotting and management of project resources
- ▶ Intuitive representation of repeating and hierarchical elements helps you create PIC layouts quickly and efficiently

Applications

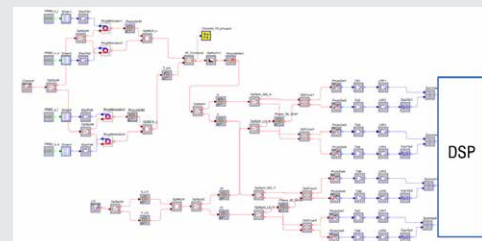
OptSim Circuit is ideally suited for computer-aided design of PIC applications and bidirectional systems, including but not limited to:

- ▶ Single- and multi-stage bidirectional PICs
- ▶ Integrated transceivers
- ▶ Integrated network subassemblies and switching fabrics
- ▶ FFTx/PON
- ▶ Microwave photonics
- ▶ Optical interconnects
- ▶ Sensing technologies, including interferometric fiber optic gyroscopes

¹ E. Ghillino, P. Mena, V. Curri, A. Carena, J. Patel, D. Richards and R. Scarmozzino, "Simulation of Silicon Photonic Coherent PM-QPSK Transceivers Using Microring Modulators," 16th International Conference on Transparent Optical Networks (ICTON), July 6-10, 2014, Graz, Austria.

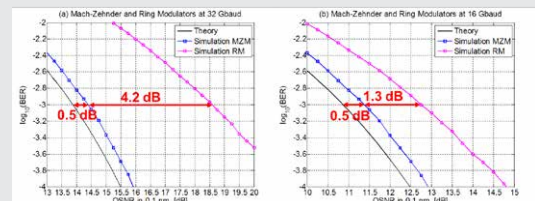
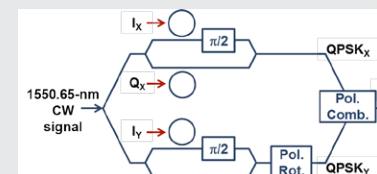
Featured Application

Simulation of a silicon photonic PIC and analysis of its performance at the system level¹. Performance analysis for the PIC is carried out for 32- and 16-Gbaud polarization multiplexed quadrature phase shift keying (PM-QPSK). Comparison is made in terms of optical-signal-to-noise-ratio (OSNR) penalty for transceivers based on lithium niobate (LiNbO₃) and silicon photonic (SiP) microring modulators.



**OptSim
Circuit
transceiver
topology**

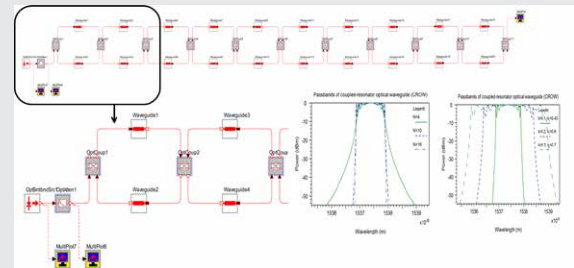
**Schematic of the
transmitter PIC**



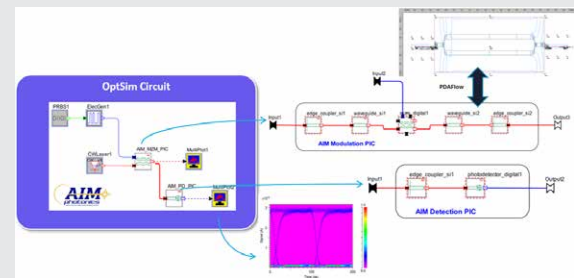
**PIC performance in terms of OSNR penalty for
32 Gbaud (left) and 16 Gbaud (right) cases**

Features

- ▶ Extends OptSim's system modeling capabilities to include PICs
- ▶ Models complex signal interactions, such as forward and backward propagating reflections and resonance
- ▶ Models bidirectional propagation for both optical and electrical signals
- ▶ Models multipath Interference (MPI) from network and PIC elements
- ▶ Includes library of PIC elements such as bidirectional waveguides, bidirectional couplers and connectors, light sources, modulators, phase shifter, ring resonator, ring modulator and photo diodes
- ▶ Includes process design kits (PDKs) from AIM Photonics and IMEC foundries and provides access to a large number of PDKs via PDAFlow interface with OptoDesigner
- ▶ Includes measurement and plotting tools, such as optical and electrical scopes, signal, spectrum and eye diagram analyzers, Q-factor and BER estimators, power meters, and more



OptSim Circuit schematic of a coupled-resonator optical waveguide (CROW) PIC



OptSim Circuit schematic and mask for a transceiver PIC using AIM Photonics PDK

SEE PAGE 41 FOR SYSTEM REQUIREMENTS

ModeSYS

ModeSYS supports the design and simulation of multimode fiber optic systems. With a primary focus on data communication applications, ModeSYS allows users to evaluate both temporal and spatial attributes of optical signal propagation. ModeSYS can be used as a standalone tool or combined with OptSim to form a comprehensive single-mode and multimode optical communication system design suite.

Benefits

- ▶ Simulates both temporal waveform and spatial modes of multimode systems combining system-level speed with device-level representation accuracy
- ▶ Provides an efficient approach based on Gloge power flow equation for modeling large-core multimode fibers
- ▶ Virtual prototyping of the multimode optical communication system for increased productivity and reduced time to market
- ▶ Fully supports yield analysis through statistical models of multimode fiber defects such as Cambridge 81 and 108 fiber models
- ▶ Interfaces with device-level tools such as BeamPROP to simulate at the system level custom components designed at the device level
- ▶ Interface with lens design tool CODE V for analysis and optimization of source-to-fiber and fiber-to-photodetector coupling and packaging problems
- ▶ MATLAB interface makes it easy to develop custom user models using the m-file language

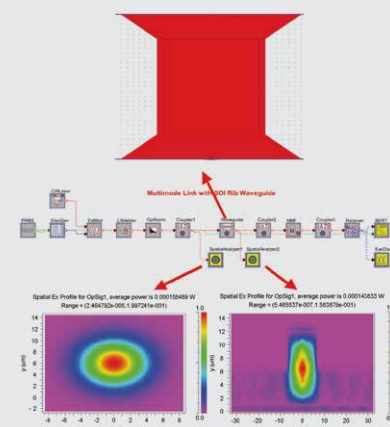
Applications

ModeSYS is ideally suited for computer-aided design of multimode optical communication systems including, but not limited to:

- ▶ Automotive and data center interconnects
- ▶ Large-Core Step-Index (LC-SI) MMF links
- ▶ Gigabit Ethernet, e.g., 1GbE, 10GbE, 100GbE, 400GbE
- ▶ 10GBASE- systems, e.g. SX, LX-4 and LRM
- ▶ Serial/WDM
- ▶ FTTx/PON
- ▶ EDC
- ▶ Optical Interconnects
- ▶ FSO

Featured Application

- ▶ ModeSYS-BeamPROP co-simulation enables the user to simulate in the context of a ModeSYS multimode system simulation a component designed at the device level in BeamPROP
- ▶ BeamPROP uses the Beam Propagation Method (BPM) to simulate custom components such as waveguides, lenses, couplers, gratings, etc.
- ▶ The figure depicts a 6-mm long waveguide with an input/output width of $14\mu\text{m}$ that tapers to $8\mu\text{m}$ within the 4-mm long central region. The substrate, core (index = 3.5) and layer (index = 1.5) materials have different indexes

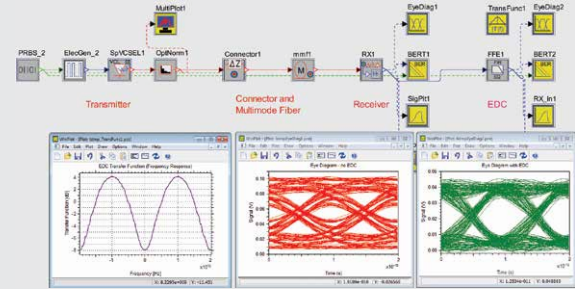


Using BeamPROP's SOI-based rib waveguide design in ModeSYS to analyze its system level performance

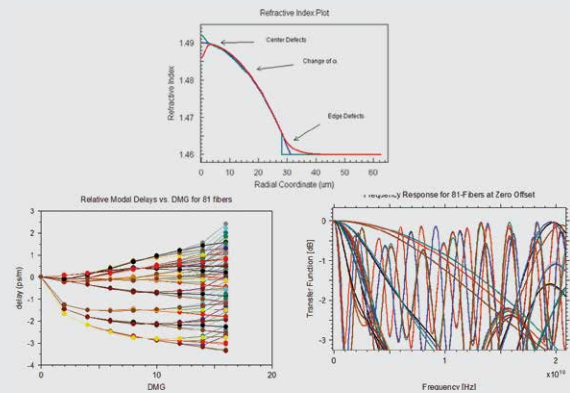
Features

- ▶ Multimode fiber model includes Helmholtz equation solver supporting arbitrary index profile and index profile perturbations
- ▶ Mode coupling due to fiber imperfections such as microbends and geometric irregularities is modeled
- ▶ Extensive set of measurement tools enables the user to analyze key characteristics of multimode optical communication systems, such as:
 - Transverse mode profiles
 - Effective modal bandwidth (EMB)
 - Signal over time
 - Differential Mode Delay (DMD)
 - Signal spectra
 - Encircled Flux (EF)
 - Eye diagrams
 - Radial power distributions
 - BER
- ▶ Mode-propagation model supports modal dispersion and Differential Mode Attenuation (DMA)
- ▶ Effects of material dispersion on group velocity are modeled
- ▶ Comprehensive spatial model using distinct transverse mode profiles supports launch-condition, optical-coupling, and alignment-tolerances analysis
- ▶ Mode coupling effects to model random exchange of powers between modes due to microbends and geometric irregularities in a real fiber
- ▶ Gloge power flow approach provides computational efficiency to the large core multimode fiber and connector models
- ▶ Extensive library of predefined manufacturer components makes it easy to model commercially available devices
- ▶ Deterministic and statistical component parameter sweeping
- ▶ Powerful encryption capabilities make protecting your schematics and model parameters easier than ever
- ▶ Co-simulation with MATLAB for implementing the custom components that operate upon transverse modes of optical signals within a multimode simulation
- ▶ Spatial interface to Synopsys' CODE V software for signal propagation through Beam Synthesis Propagation (BSP) and FFT Beam Propagation (BPR) analyses
- ▶ Application Programming Interface (API) for programming languages such as C/C++ for the development of custom user models

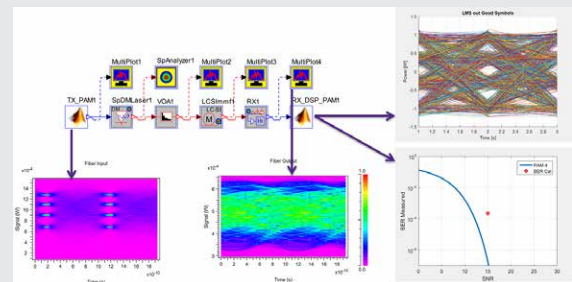
SEE PAGE 41 FOR SYSTEM REQUIREMENTS



Modeling of Electronic Dispersion Compensation (EDC) in ModeSYS. ModeSYS and OptSim include FFE- and DFE-based EDC with MMSE-based optimization



Studying the impact of refractive index profile perturbations using Cambridge-81 and Cambridge-108 models in ModeSYS



Analyzing PAM-4 transmission in Large-Core Step-Index (LC-SI) MMF-based system in ModeSYS

Professional Services and Programs

Synopsys' Optical Solutions Group provides a variety of professional services and programs that supplement and support our client's need for a total solution.

Training Seminars

We organize product training seminars every year. Seminars are either hosted at our offices or by a host sponsor, including many prominent universities. Private seminars are also available at an additional cost.

Customized Solutions

In order to address the needs of specialized applications, we offer consulting services to extend the current capabilities of our software tools. Customized solutions accelerate product development and reduce client time to market.

Design Services

We offers supplemental consulting services, ranging from application design optimization to full product design. Typical applications include promoting a faster learning curve with the software tools and exploring possible what-if concepts. This can be especially useful if company resources are limited.

For more information on our professional services and programs, please contact Synopsys' Optical Solutions Group at rsoft_sales@synopsys.com.

To Learn More

For more information about the RSoft products and to request a demo, please contact Synopsys' Optical Solutions Group at (626) 795-9101 between 8:00 a.m.-5:00 p.m. PT, visit <http://optics.synopsys.com> or send an email to rsoft_sales@synopsys.com.

In addition, we have software distributors throughout the world. A full list of our distributors can be obtained at our website, <http://optics.synopsys.com/support/support-global-contacts.html>.

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