RSoft CAD ENVIRONMENT

COMPONENT DESIGN
Passive Device

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 RSoft's 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

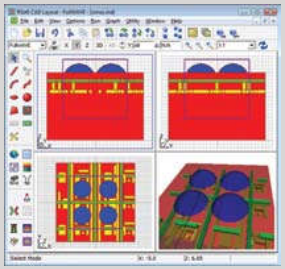
- Highly flexible design environment allows virtually any geometry to be created.
- Included with each of RSoft's passive component simulation tools.
- Provides a unified platform for RSoft's passive component simulation tools; designs do not need to be imported from one software package to another to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

Layout *Capabilities*

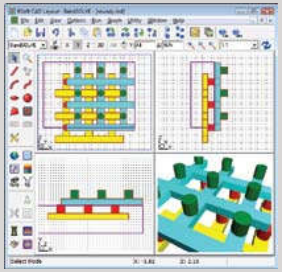
The RSoft CAD Environment has been designed from the ground up to accommodate the special needs of photonic devices and circuits. Fundamental objects such as straight, tapered, and curved components, lenses, and polygons can easily be selected from the toolbar and graphically added to the circuit using 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 can have 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, the entire circuit can be modified by simply changing the value of a single variable without having to edit multiple parts of the structure.



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.

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.
- 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.
- Includes layout utilities for common periodic structures, grating structures, and AWG structures.
- Includes WinPLOT, RSoft's technical graphing program.
- Includes DataBROWSWER which allows users to quickly browse and view results.
- Several utilities are included for custom pre- and post-processing capabilities including interfaces with popular ray-tracing software packages.

SEE **PAGE 41** FOR SYSTEM REQUIREMENTS

BeamPROP

COMPONENT DESIGN
Passive Device

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

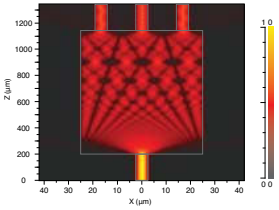
- Industry-proven BPM algorithm for fast and accurate device design.
- Built-in advanced AWG utility for simplifying router and demultiplexer design.
- Advanced capabilities allow for the simulation of complicated devices.
- Fully integrated into the RSoft CAD Environment *(Page 6)*.

Applications

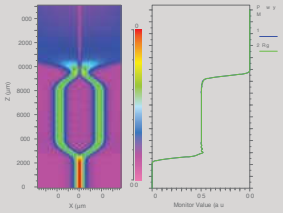
BeamPROP has applications in a wide range of integrated and fiber-optic devices including, but not limited to:

- WDM devices such as arrayed waveguide grating (AWG) routers
- Switches, e.g. directional coupler-based or digital-y type
- Modulators, e.g. 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

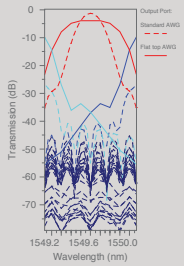
Featured *Application*



BeamPROP simulation of a 1 x 3 MMI device. The length of the MMI was optimized so that the three output waveguides contained equal power.



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



BeamPROP simulation of a at-top AWG. The taper on the input port was designed to produce the at-top response shown. The standard AWG output is also shown as reference.

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.
- Non-uniform mesh.
- Anisotropic and non-linear materials.
- Fully intergrated with Multi-Physics Utility *(Page 28)*.
- Polarization effects and coupling via a full-vectorial BPM implementation.
- techniques, a variable reference wave number, and conformal index mapping of bends to allow for accurate and efficient off-axis propagation.
- 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 fields, power distribution, loss, etc.
- Automated parametric studies and design optimization using MOST *(Page 24)*.

SEE **PAGE 41** FOR SYSTEM REQUIREMENTS

FullWAVE

COMPONENT DESIGN
Passive Device

FullWAVE is a highly sophisticated simulation 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. The software employs the Finite-Difference Time-Domain (FDTD) method for the full-vector simulation of photonic structures. FullWAVE's award winning innovative design and feature set has made it the market leader among optical device simulation tools.

Benefits

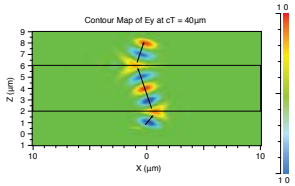
- Cutting edge implementation of mature FDTD algorithm allows for a wide range of simulation and analysis capabilities.
- Advanced capabilities allow for clustered simulation environment for massive computational increases in speed and efficiency.
- Fully integrated into the RSoft CAD Environment *(Page 6)*.

Applications

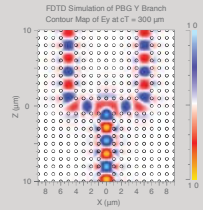
FullWAVE has applications in a wide range of integrated and nano-optic devices including, but not limited to:

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

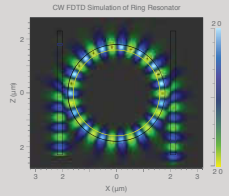
Featured *Application*

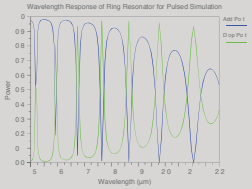


Demonstration of negative index refraction with the propagation of a beam through a left handed material bounded by air.



FullWAVE CW simulation of photonic bandgap y-branch structure.





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

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

FEATURES

- 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.
- Full control of dispersion, non-linear (X^2 and X^3), and anisotropic effects.
- Frequency-dependent saturable gain model.
- Includes Perfectly Matched Layer (PML), 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 power flux, energy densities, overlap integrals, far fields, and the Poynting Vector. Additionally, both FFT and DFT options are included for frequency analysis.
- Includes Q-Finder, a utility that automates the search for cavity modes and Q-factors.
- Automated parametric studies and design optimization using MOST *(Page 24)*.
- Increased performance through parallel processing via multi-cpu/core machines and/or clustering across a network of computers. Contact RSoft for licensing policies regarding this feature.
- A native 64-bit version of FullWAVE is available that takes advantage of modern 64-bit CPUs that support additional system memory (RAM).

SEE **PAGE 41** FOR SYSTEM REQUIREMENTS

DiffractMOD

COMPONENT DESIGN
Passive Device

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

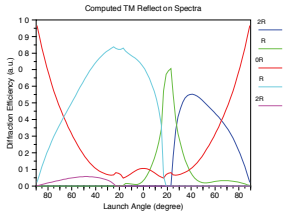
- Incorporates advanced algorithm options that extend the basic RCWA technique to improve its robustness, efficiency, and user-friendliness.
- Fully integrated into the RSoft CAD Environment *(Page 6)*.

Applications

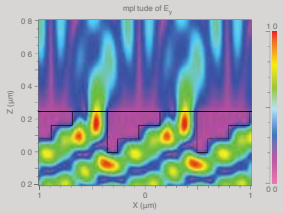
DiffractMOD can handle complicated periodic structures containing both dielectric and metallic components with lossy or dispersive materials. It has application to a wide-range of devices including, but not limited to:

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

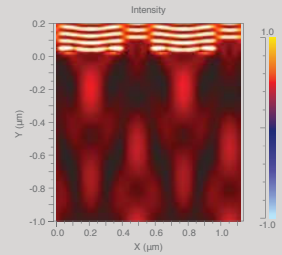
Featured *Application*



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



Field profile of metallic grating structure.



Simulation of a Phase Shift Mask with DiffractMOD.

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.
- 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.
- Sophisticated field output options allow the user to calculate and display field profiles at any position.
- Spectrums vs. wavelength, angle and polarization for any diffraction efficiency can easily be computed.
- Output common metrology parameters directly.

SEE **PAGE 41** FOR SYSTEM REQUIREMENTS

GratingMOD

COMPONENT DESIGN
Passive Device

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

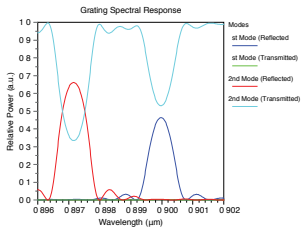
- Incorporates advanced algorithms to improve its robustness, efficiency, and user-friendliness
- Fully integrated into the RSoft CAD Environment *(Page 6)*.

Applications

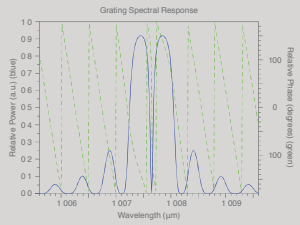
GratingMOD can handle various grating structures for both fiber and integrated waveguides. It has applications to a wide range of integrated and fiber-optic devices including, but not limited to:

- Dispersion compensation Fiber Bragg Grating
- Multiplexing/Demultiplexing
- Add/Drop filtering
- Gain equalization in optical amplifiers
- Grating assisted couplers
- Long period grating sensors

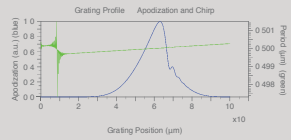
Featured *Application*

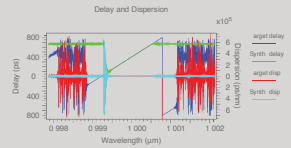


Results for multimode simulation of a grating assisted coupler. Spectra are shown for both forward & backward propagation for both modes in the structure.



Simulation results showing the phase and amplitude.





Synthesis results of a grating with constant dispersion compensation.

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.

SEE **PAGE 41** FOR SYSTEM REQUIREMENTS

MOST

MOST†, RSoft's Multi-varable 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 under stand the full parameter space of the system. Acting as an automated driver for RSoft's 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

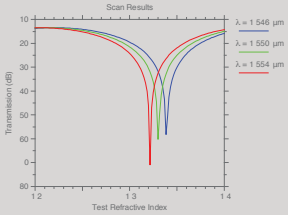
MOST is applicable to any situation where a range of parameters need to be looked at or optimized including, but not limited to:

- 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

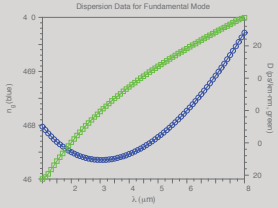
Simulation *Technology*

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 Diffract-MOD. 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 distribted scanning are licensed seperately.



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.

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 pharameter 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.

SEE **PAGE 41** FOR SYSTEM REQUIREMENTS