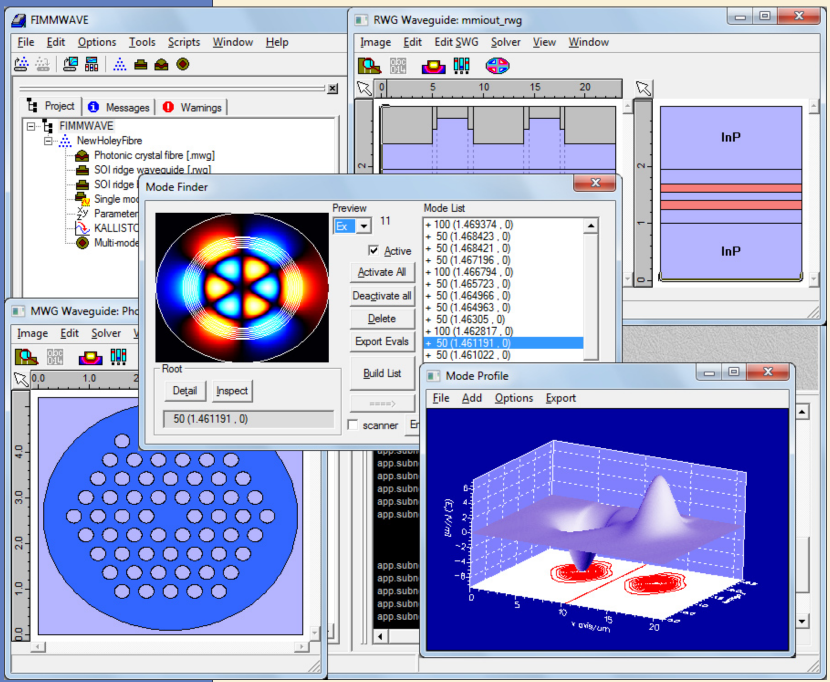
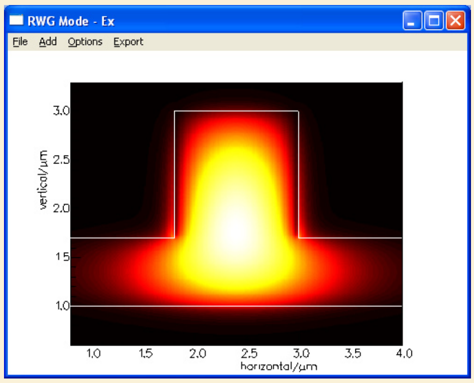
FIMMWAVE

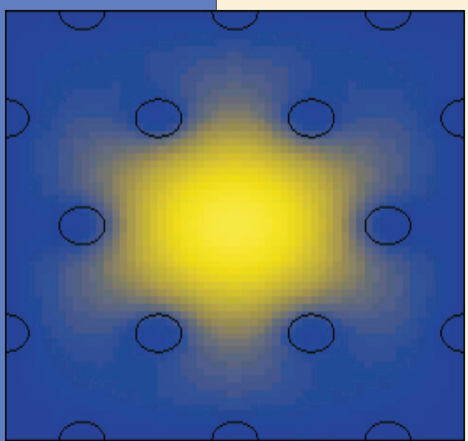
a fully vectorial 3D mode solver



- ☑ fully vectorial solution of near arbitrary 3D waveguides
- ☑ variety of fast, robust Solver Engines, each optimised for rectangular geometries, fibres or diffuse guides
- ☑ complex versions for waveguides of complex refractive index, including metals



- ☑ very accurate solutions even for “difficult” problems such as devices with very thin layers, weakly coupled structures, and devices near cut-off
- ☑ comprehensive material database
- ☑ parameter scanners for rapid design



- ☑ friendly interface with wide choice of editors for designing rectangular, circular or diffuse waveguides or as a set of geometrical shapes
- ☑ diagonal and general tensor anisotropy supported
- ☑ bend mode solvers
- ☑ accurate also for high order modes

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What is FIMMWAVE?

FIMMWAVE is a generic, robust, fully vectorial mode finder for 3D waveguide structures, which may be of almost any geometry, such as SOI, polymer, etched GaAs/AlGaAs waveguides, diffused $LiNbO_3$ as well as single and multicore fibres.

FIMMWAVE contains a variety of robust and computationally efficient solvers optimised for either generic rectangular structures, often encountered in opto-electronics, or circular fibres with generic refractive index profiles. A lot of original work has been put into this product to make these solvers extremely reliable. FIMMWAVE can also use approximate versions of these methods - ideal for rapid prototyping.

A flexible design interface

FIMMWAVE comes with a set of professional visual design tools for designing waveguides for rectangular geometries often encountered in integrated-optics, circular geometries for the design of fibre waveguides and also more generic geometries. Multiple cores may also be easily specified, thus making the analysis of fused fibres a simple operation.

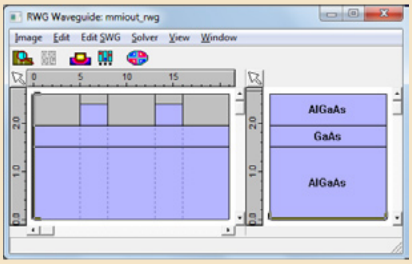
The program can model passive devices or (with the Complex Engine), near-arbitrary complex devices, e.g. with gain or metal layers.

The program comes with sophisticated visualisation tools for easily analysing mode profiles, such as quick previews, 2D contour plots, 3D mesh plots etc. The user may add text and lines to these graphs. All graphs can be readily printed or exported. ASCII files of most results may be generated for export to other programs.

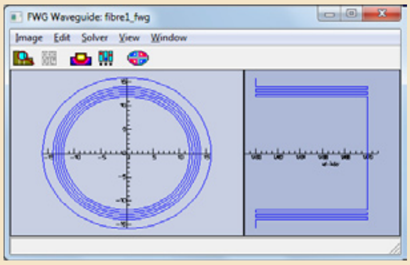
The Molab

The Molab (mode list auto builder) is a sophisticated algorithm that fully automates the finding of eigenmodes. The Molab interface is simple and flexible, so that you can just say “first 3 TE modes please” or “all modes with an effective index between 3.14 and 3.0” etc. The Molab all but guarantees to find all the optical modes of a structure, including some of the most difficult structures such as devices with degenerate modes. For example, a structure which has a TE and a TM mode that have near identical propagation constants are found without resorting to ridiculously fine search grids. The Molab is fully implemented for both the real and complex solvers.

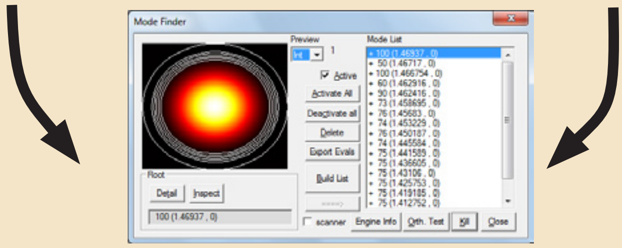
Professional waveguide design interface



The rectangular waveguide editor



The circular waveguide editor



The mode finder

Modelling Surface Plasmons

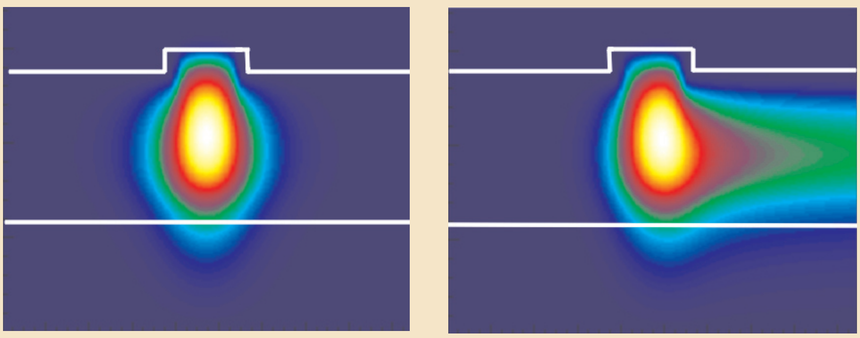
Most of FIMMWAVE's mode solvers can readily and accurately compute surface plasmons. Here we use the FDM Solver to compute the modes along a 10nm silver plate buried in a dielectric layer. The intensity profile of the fundamental TM-like mode can be seen below.

Surface plasmon mode: intensity profile

Ring Resonators... finding bend modes

All three FMM, FEM and FDM Solvers can be used to calculate bend modes to simulate for instance the propagation of light around a bend or a microring or a microdisk.

You can compute the effective index and bend loss of the bend modes using fast algorithms. Rigorous solutions are obtained by using cylindrical coordinates.



Modes of a straight and curved rib waveguide

You can just say 'first 3 modes please' or 'all TE modes with an effective index between 3.14 and 3.0'

A variety of robust solvers

The solvers currently implemented in FIMMWAVE are:

The FMM Solver: This solver, based on the mode matching method, is optimised for rectangular geometry waveguides such as epitaxially grown structures. It is fully vectorial, and there is either a generic version capable of solving structures with complex refractive index (such as metallic components and waveguides with gain), or a version optimized for real-index structures only.

The method also features a true transparent boundary condition on sides - efficiently dealing with modes that are **near cutoff** in the lateral direction and bend leakage without loss of accuracy.

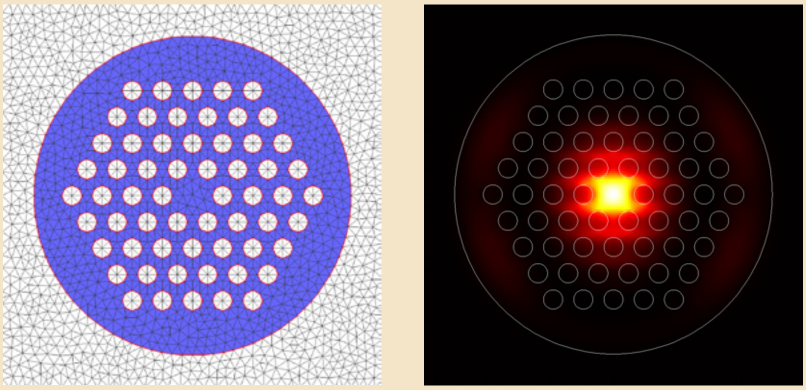
The FMM Solver does not use a grid and is therefore ideal for structures with very thin layers, modelling these accurately and with ease.

Boundary conditions: PML, magnetic, metallic, periodic, impedance, true transparent.

Anisotropy: supports a diagonal tensor. with $\varepsilon_{11}=\varepsilon_{22}\neq\varepsilon_{33}$.

Finite Element Mode Solver

The FEM Solver is ideal for waveguides with curved interfaces such as Photonic Crystal Fibres. It is also ideal for diffused waveguides and waveguides with slanted walls.



FEM Mesh and mode profile for a photonic crystal fibre

FDM Solver: The Finite Difference Mode Solver uses a rectangular grid. Unique and highly advanced techniques allow features smaller than the grid size to be accounted for accurately. It supports gain/loss, PMLs, a diagonal dielectric tensor, graded index structures and can find bend modes. This is a very fast, reliable solver and will solve most waveguide problems to good accuracy.

Includes magnetic, metallic, impedance, periodic boundary conditions.

FEM Solver (Opt09): The Finite Element Mode Solver features an unstructured triangular grid, making it ideal for waveguides with curved interfaces, very small features and graded index areas. It supports PMLs, a diagonal dielectric tensor and bend modes. Ideal also for finding surface plasmon modes on metals. It is in general more accurate than FDM but slower.

Bend Mode Solvers: A variation of the FMM, FEM and FDM Solvers will compute the modes of a bent waveguide, i.e. solutions of the form $\Psi(x,y,s) = \Psi(x,y).e^{i\beta s}$. The methods used include a rigorous cylindrical coordinate formulation which can model the tightest bends accurately. Computes bend loss, effective index and distortion of the mode profile.

Effective Index Solver: This well known approximate method is both a fast and reliable way of finding estimates for 3D modes for near 2D waveguides (many ridge structures fit into this category). The solver uses our own 2D solver (also used in the FMM solver) which makes it extremely robust. In particular it can deal with structures with completely decoupled cores.

Cylindrical Solvers (Opt 06): This is a fully vectorial solver for generic circular waveguides with arbitrary refractive index. It will find all the modes of such structures using metallic or transparent boundaries. Although it is a fully vectorial solver it exploits the circular symmetry, thus making it extremely fast. A scalar version is also included.

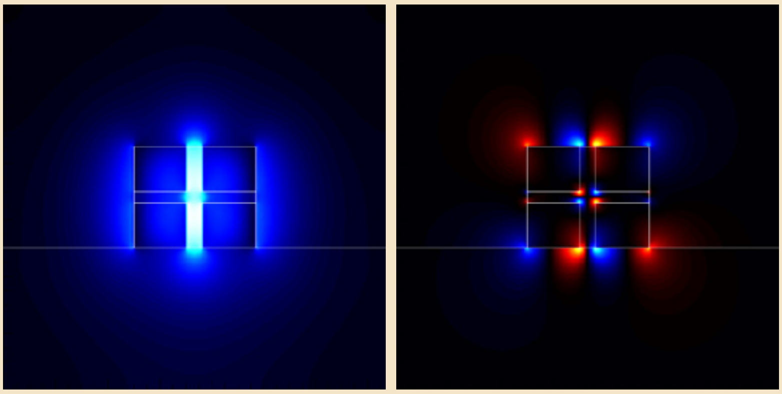
Gaussian Mode Fibre Solver: This is a quick utility for getting the fundamental mode using the gaussian approximation. The user simply specifies the effective index and the spot size of the desired mode - useful where the fibre profile is not known.

Fully Vectorial Solvers

The use of fully vectorial solvers allows you to model accurately structures of high-index contrast such as SOI.

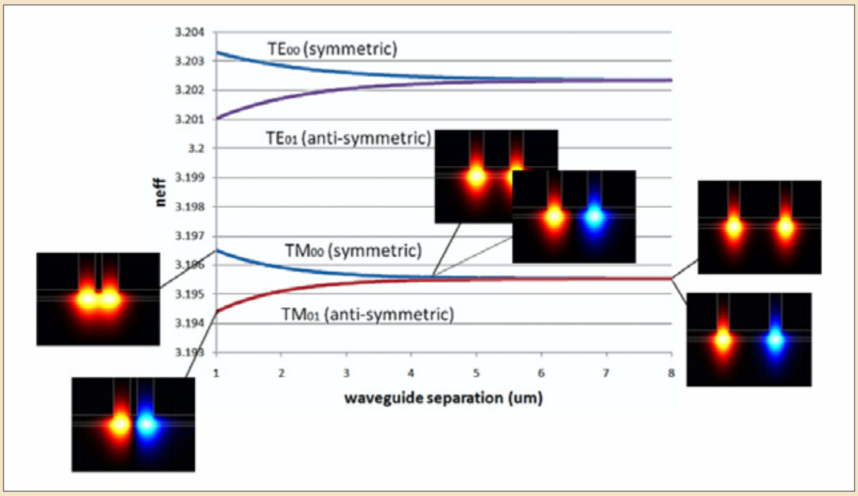
FIMMWAVE gives you field profiles for all six E and H field components, allowing you to model subtle polarisation effects.

The pictures on the right show the Ex and Ey field profiles of the fundamental TE-like mode of a slot waveguide calculated with the FDM Solver.



Ex and Ey field profiles of the TE_{00} mode of a slot waveguide

Design waveguides using the scanning tool...



Parameter scanners permit design optimisation in a rapid simple manner. Here we see the even and odd modes of a twin ridge waveguide become degenerate as the guides are moved apart.

A variety of design utilities

Mode Analysis: The following data is available for each mode:

- confinement factor
- overlap integral with material loss profile of waveguide
- effective index and propagation constant
- dispersion and group velocity
- effective mode area

Parameter Scanners: These routines will allow you to rapidly generate design curves of almost any calculated parameter as a function of almost any input parameter or dimension.

Thermal/EO Module (opt 07): This includes a 2D Poisson Solver for studying the response of your waveguides to thermal and electrostatic fields. Applications include thermo-optic and electro-optic switch design. Please ask for more details.

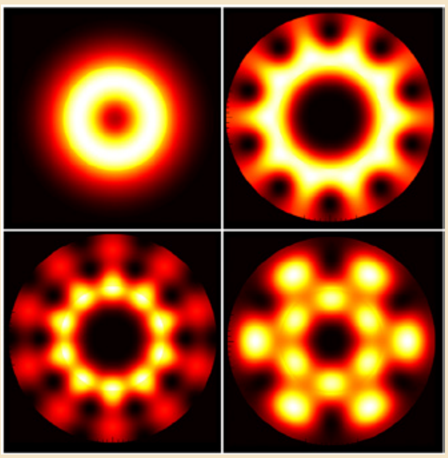
Farfield Calculator: Calculate far field of an eigenmode using vectorial formulae in spherical or planar projection, or aperture flux (for photodetector simulation).

Platforms

PC: XP/Vista/Win7, 2GB RAM, Core2Duo 1GHz or better recommended

Parameter scanners permit design optimization in a simple manner.

FIMMWAVE is readily extendible with farfield calculators and a thermal module.



Cylindrical Solvers

(Option 06) FIMMWAVE features two solvers dedicated to cylindrical geometries, relying on the use of Bessel functions and on a finite-difference method.

These solvers can model arbitrary waveguides of cylindrically symmetric profiles, using fully vectorial, fast and accurate algorithms. The complex version will allow you to model absorbing fibres and metal layers. You can select the modes to calculate by selecting your criteria of axial order, polarisation, etc.

You can define your optical fibre as a number of concentric cylinders or import automatically your own profile data which can be fitted using a cubic spline.

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