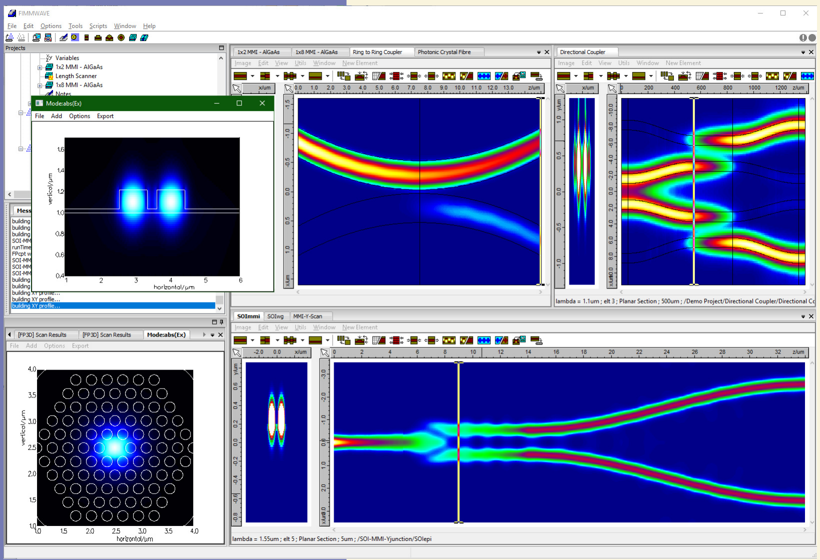
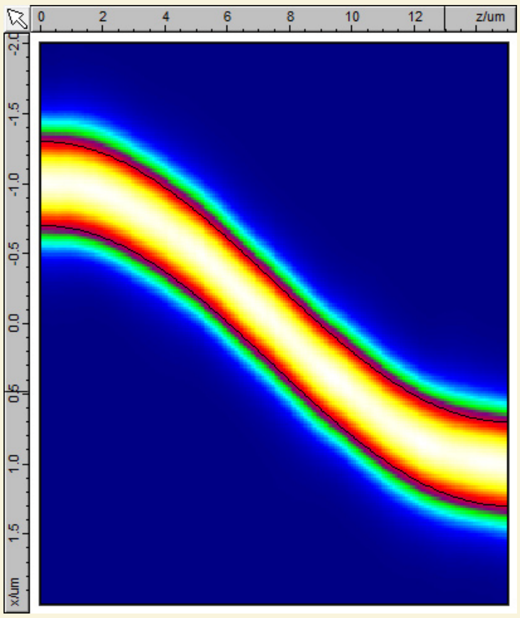
FIMMPROP

a bi-directional optical propagation tool



- ☑ Rigorous Maxwell Equation solver for semi analytical, fully vectorial 3D propagation
- ☑ High index contrast capability: can easily model silicon photonics and III-V devices
- ☑ Model wide-angle problems - no slow-varying approximation
- ☑ Bidirectional algorithm models all internal reflections
- ☑ Fully compatible with FIMMWAVE's suite of rigorous mode solvers

- ☑ Scattering matrix approach for fast design optimisation
- ☑ Fast design of MMI couplers, periodic structures, tapers and bends!
- ☑ Much more accurate than BPM for high-index devices
- ☑ Much faster than FDTD for most waveguide structures
- ☑ Flexible design interface for near arbitrary structures



- ☑ EME (EigenMode Expansion) provides great physical insight into your devices
- ☑ Sophisticated field visualisation, study mode power evolution, etc.
- ☑ Closely integrated with PicWave for large circuit design

Photon Design®

Photon Design Ltd
34 Leopold St.
Oxford, OX4 1TW
United Kingdom

Tel: +44 1865 324990
Fax: +44 1865 324991
Email: info@photond.com
Web: www.photond.com

What is FIMMPROP?

FIMMPROP is an innovative tool for simulating 2D and 3D optical propagation in waveguides.

At the heart of FIMMPROP is a robust calculation engine based on a sophisticated EME (EigenMode Expansion) algorithm invented by Photon Design in 1997, capable of giving rigorous solutions to the wave equations. This makes it possible to find solutions which are **fully vectorial** and **fully bi-directional**, taking into account all the reflections at intermediate joints.

This makes FIMMPROP capable of correctly modelling structures which are unsolvable by other methods such as BPM, including high index contrast structures used in silicon and III-V semiconductor photonics.

The algorithm has been refined and speed-optimised over many years, so that even structures solvable using other techniques can often be simulated in a fraction of the time.

The flexible design paradigm makes it very easy to model complicated systems, by assembling predefined components such as simple straight sections, bends, tapered and periodic structures, and then inserting the resulting component into other user assembled components.

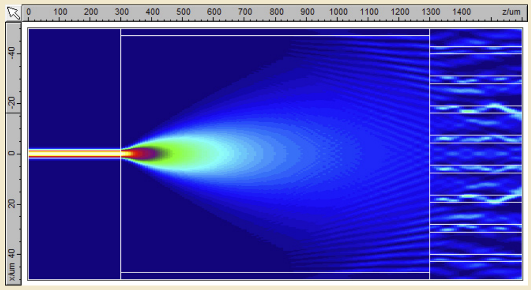
The ease of use and calculation speed make FIMMPROP the ideal tool for designing a wide range of devices such as tapers, MMI couplers, mode converters, codirectional couplers (e.g. polarization converters), splitters.

Optimising an 1x8 MMI Coupler

FIMMPROP was used to model in 3D a 1x8 MMI coupler based on a AlGaAs/GaAs rib waveguide geometry at a wavelength of 1.103um.

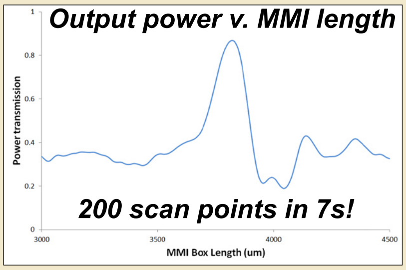
The length of the central section and the lateral positions of the output waveguides were optimised using scanners. **The optimal coupling length was obtained within seconds,** giving a total power transmission of 92.4%.

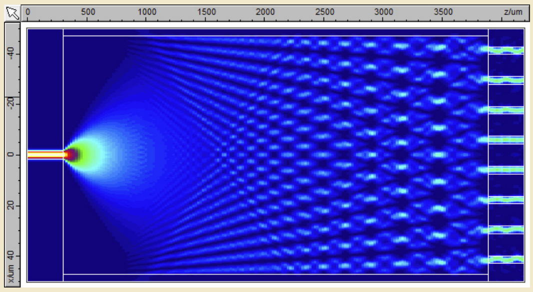
Thanks to the scattering approach of EME, once the eigenmodes are known for each section of the device, recalculating the output field after having varied the length of any section is instantaneous. Optimising the same design with a BPM algorithm would require unrealistic length of times - not to mention the fact that BPM would make large approximations in order to model such a large range of angles!



Get from this...

...to this, within seconds!





Calculation method

Propagation is done by EME. Z-varying structures are modelled by joining two or more straight sections together. Once the local modes of the structure are found then propagation along the length of the section is *near-instantaneous*. Calculations permit both transmission and reflection coefficients of the modes at each joint to be determined for use in the fully bi-directional propagation algorithm. The algorithm builds a scattering matrix description of the device and all its elements, which means that once the matrices are generated, you can obtain the response to many different input profiles without further computation, e.g. one might want response to both TE and TM excitation. Furthermore, if you alter the structure, the routine needs only recalculate the elements that have changed.

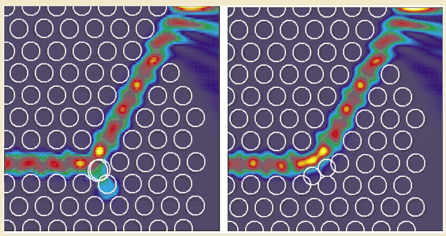
Propagation in free space, occurring for example between a laser facet and a fibre, is treated with an efficient dedicated plane-wave expansion algorithm.

What is EME?

EME stands for **EigenMode Expansion**, a powerful algorithm for the modelling of light propagation in optical waveguides. It is an ideal tool for the modelling of many devices in integrated optics and it is in particular widely used in silicon photonics thanks to its high-index contrast capability.

- Intrinsically bi-directional
- Fast modelling tool, in many cases much faster than BPM or FDTD
- Model a wide range of angles (e.g. for SOI MMI couplers)
- Improvements invented by PhotonDesign avoid staircasing problems
- Highly efficient to model long devices
- Fast design optimisation: scattering matrix structure allows quick updating of results when scanning parameters
- Physical insight into the physics of the device

For more information about EME you can visit our website: www.photond.com/products/eme.htm



EME is such a powerful method that FIMMPROP can even accurately model photonic band gap crystals! The bent photonic crystal waveguides above were evaluated in less than a minute.

Features:

- Bidirectional
- Rigorous Maxwell equations solver
- Wide angle
- Fast!
- Very efficient for long devices
- Material database system
- Parallelised algorithms for modern CPUs

Applications:

- Silicon Photonics
- Ring resonators
- Tapers
- Spotsize converters
- MMI couplers
- Directional couplers
- Polarisation converters
- Fibre to chip couplers
- Lensed fibres
- Bends
- Gratings
- Plasmonics
- Thin Film Filters

etc.

A powerful design interface

FIMMPROP offers many flexible ways to design Z-varying structures with arbitrary variations of dimensions and refractive indices. Bent waveguides of fixed curvature can also be created and simulated easily.

The modular nature of the method employed is fully exploited by FIMMPROP in its flexible, modular design paradigm purposely made to take advantage of any symmetries or repetitions in the *components* you create.

In addition, FIMMPROP also allows you to insert *at arbitrary depth* any component you design into another component. This not only allows you to build complex structures easily, but it also enables FIMMPROP to fully exploit the symmetries and repetitions in your structure.

Scanning tools

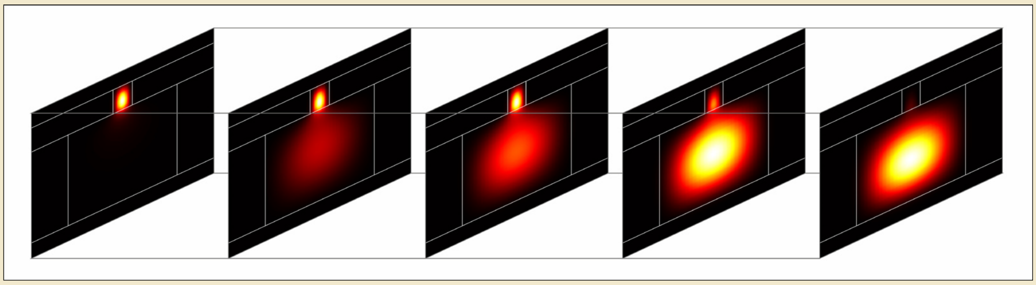
Much attention has been paid to efficiency, so that when any parameter of the structure is changed, only the minimum amount of recalculation is done. In particular, if any parameter is changed which leaves the cross sections unaltered (e.g. the lengths, offsets and tilts) then recalculation of the signal propagation in the modified structure is very fast. To exploit this fact, FIMMPROP comes with a *general scanner* which allows you to vary the structure parameters continuously. This provides a quick and intuitive graphical way of optimising your structure, slashing the design cycle in a way unachievable using other numerical methods.

Bi-directional Algorithm

FIMMPROP's bi-directional algorithm is inherently stable. Most attempts at bi-directional propagation are iterative: they propagate the reflections back and forth a finite number of times, by which time the amplitude is hopefully small. Such an algorithm cannot cope efficiently with highly reflecting structures. FIMMPROP's bi-directional scattering matrix approach can cope with any number of reflecting interfaces, even very highly reflecting ones. This feature alone opens up many new applications. For example, the program can simulate ***resonating cavities*** such as Fabry Perot structures, and ***photonic bandgap crystal*** structures.

Design adiabatic tapers, Y-junctions, spot-size converters...

FIMMPROP is ideal for designing continuously varying structures such as Y-junctions and tapers where near-adiabatic performance is sought. The program is able to determine how long a structure must be to achieve adiabatic coupling much more rapidly than traditional optical propagation techniques. Moreover, tapers can be modelled with arbitrarily wide angles and high refractive index contrast, since FIMMPROP makes no approximations whilst solving Maxwell's equations. You can see below the evolution of the intensity profile along a tapered spot-size converter.



Spot size converter modelled in FIMMPROP: the core of the top waveguide is tapered down in order to couple the intensity to the substrate.

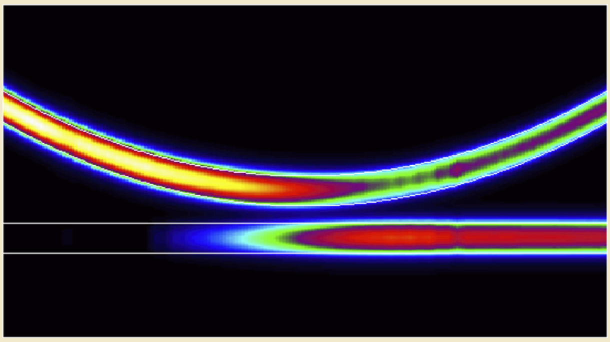
Model SOI ring resonators the smart way

FIMMPROP can model the coupling region of ring resonators in 3D with a very high accuracy in a few tens of minutes, even for large ring diameters that cannot be solved with the FDTD method (at least not without hundreds of clustered cores and a few weeks of computation time!).

EME allows you to solve the structure in terms of local modes, a very efficient way to model coupling. The coupling coefficient is given in terms of the bend modes in the ring, allowing you to inject it directly into your analytical model.

Plug-in the properties of the bend modes calculated with FIMMWAVE and you can easily calculate the response of a single ring resonator in a fraction of the time it would have taken you to get a rough estimate in FDTD.

Complex ring resonator circuits can be handled with the help of our photonic circuit simulator PICWave, to which the results can be easily exported.



Intensity profile for an SOI ring coupler modelled in 3D

Client-Server Interface

Almost the whole of the program may be controlled over a TCP/IP link to your own programs. Not only can any parameter be altered, any structure built up, but all the results may be sent back to your own algorithms for sophisticated optimisation and the like. Sample client program code is provided.

Graphical tools

FIMMPROP comes with sophisticated visualisation tools, allowing you to view the forward, backward or total propagating fields in the longitudinal direction, as well as the cross sectional field at any point along the structure. You can visualise at a glance the power of any mode as a function z (propagation direction), as well as the mode profiles.

Platforms

PC: Win7/Win10, 2GB RAM, 64-bit CPU, 4-core or better recommended

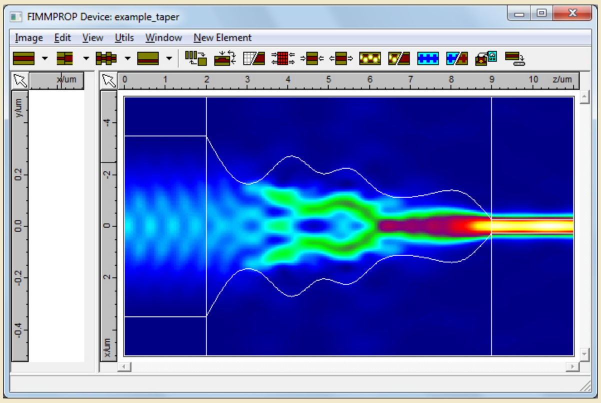
FIMMPROP can accurately model strong reflections caused by facet coatings (even highly resonant cavities!)

Short taper optimisation with Kallistos

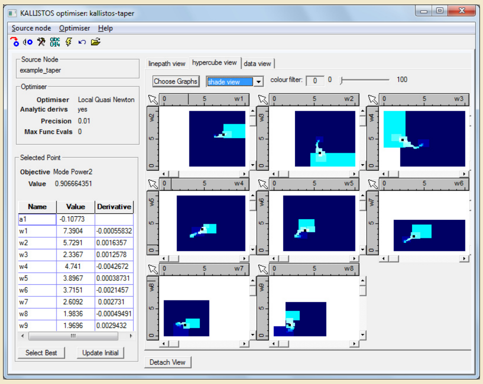
FIMMPROP combined with our generic optimisation tool Kallistos was used to optimise the lateral profile of a short 7µm-long taper in order to maximise its transmission.

A local optimiser allowed us to scan a very wide range of profiles and eventually converged to the rather unusual shape shown below, for a total transmission of 92%. To achieve such a transmission, a linear taper would have needed a length three times longer.

The optimisation was performed on nine independent parameters defining the width at different positions of the taper. The taper profile was generated from these parameters using a spline fitting.



This optimised profile gives a 92% transmission, for the same length a linear taper only transmits 54%!

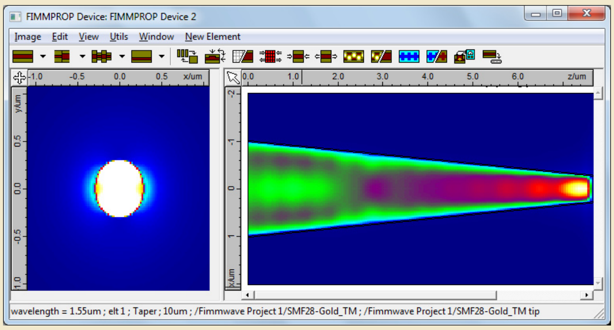


View of the optimisation data in the parameter space

Modelling propagation in fibre devices

FIMMPROP can use FIMMWAVE's fully vectorial fiber solvers which rely on a finite difference method and the use of Bessel's functions. This allows FIMMPROP to model devices such as fibre tapers, fibre Bragg gratings, as well as any device with a cylindrical symmetry, including metallic structures.

Below is metal-cladded tapered fibre for Scanning Near-field Optical Microscopy (SNOM) modelled wtih FIMMPROP. The glass fibre is covered by a thin metal layer of thickness 22nm. Its core is tapered from a radius of 1um to 300nm on a length of 7.5um. The cross-section on the left-hand side shows the field profile at the tip.



Metal-cladded tapered fibre for scanning near-field optical microscopy

Photon Design®