Could your simulations run
orders of magnitude faster ?

3D Delay Line simulation in FIMMPROP; over 2cm of optical path length simulated in less than a minute.

FIMMPROP

- The Market's Leading EigenMode Expansion Engine
- Simulate 3D Waveguide Devices + Fibers
- Much Faster Than FDTD in Most Applications

Photon Design have been serving the photonics community for over **30 Years** with market-leading software for designing passive components, active components, and entire PICs. All of our tools are under continuous development driven by the feedback of our users and their cutting edge research.

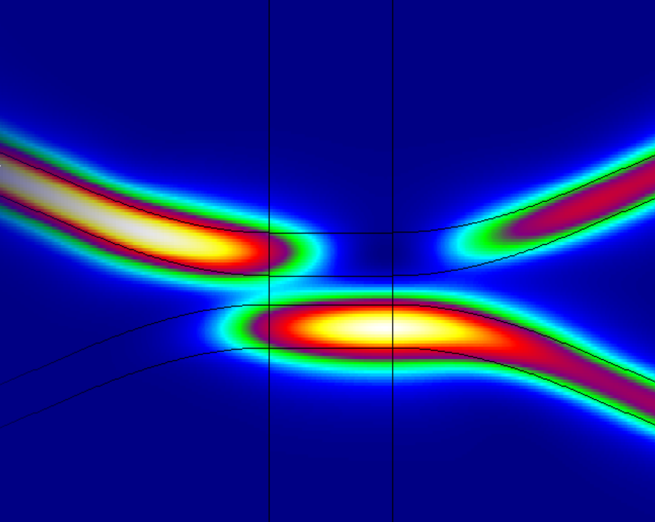
info@photond.com
www.photond.com

What is EME?

FIMMPROP uses EigenMode Expansion (EME), a rigorous Maxwell Equation solver for performing 3D simulations of waveguide devices such as PIC components and fibers. Photon Design invented the first viable EME in 1998 and continue to pioneer the method, leading innovations with exclusive advanced features.

How does it work?

A FIMMPROP device consists of multiple connected waveguides including variable curvature bends, tapered and branching waveguides. Optical modes are calculated at multiple cross-sections along the FIMMPROP device. Propagation between these cross-sections is described by a scattering matrix. The result; a ***fully vectorial*** description of how an arbitrary input propagates along your device decomposed into its modes.



3D Directional Coupler Simulation in FIMMPROP

Advantages of EME

- **Rigorous** – EME is a rigorous solution to Maxwell's equations with no forced approximations. Results will be identical to other rigorous methods like FDTD where both methods are applicable and set up correctly.

- **Fast** – **No cloud computing required.** Coupling, tapering, and bending waveguide sections simulate in reasonable times on a standard laptop to convergent results. Simulations along straight/constant curvature waveguides are comparatively instant **regardless of length**.

- **Efficient** – Recycle calculations from repeated, symmetric, and periodic structures for faster simulations (not possible in time domain simulations such as FDTD).

- **Instant Recalculation** – Changing the input to a device does not require any recalculation thanks to the scattering matrix approach. Results of any arbitrary input are instantly at your fingertips.

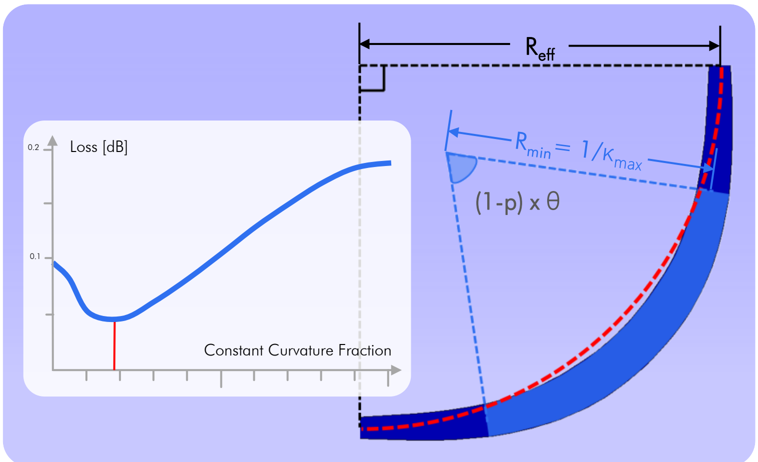
- Allows simulation of reflections, high refractive index contrast, wide angle propagation, anisotropy and more.

Minimise Bend Loss Near Instantly

FIMMPROP accurately simulates the physics of bend propagation by describing fields naturally through a basis set of *bend modes*. Due to this, ***constant curvature bends can be simulated blisteringly fast***.

Build any bend in FIMMPROP by describing a path with an arbitrary function such as low loss partial Euler bends or a spline. Advanced bend designs can also be tapered as shown (right) to minimise loss.

As a fast frequency domain simulation, FIMMPROP excels in rapid iterative design, allowing users to **quickly minimise bend losses** (simulated with a range of absorbing boundary conditions) or higher order coupling.



Tip: Parameter Sweeps
Use FIMMPROP's native scanner to sweep the curvature of a waveguide to find its tightest bend before loss occurs.

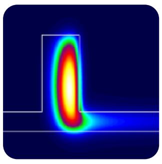
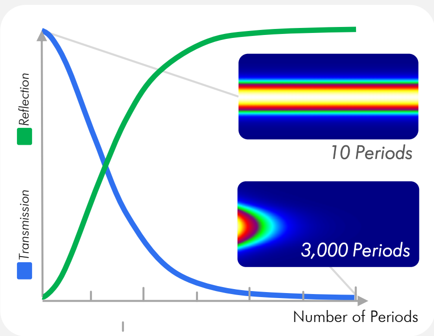


Image: Partial Euler bend with varying width optimised using FIMMPROP's native scanner. Light blue section shows region of constant curvature, red dashed line shows reference constant curvature path.

Periodic Structures + Gratings



EME provides incredibly efficient simulations for periodic structures, ***exploiting symmetry by reusing results*** of a single period calculation, permitting DBR gratings to be simulated almost as quickly as a straight waveguide. FIMMPROP's native scanner can quickly find how many periods are needed for a desired grating reflectivity.

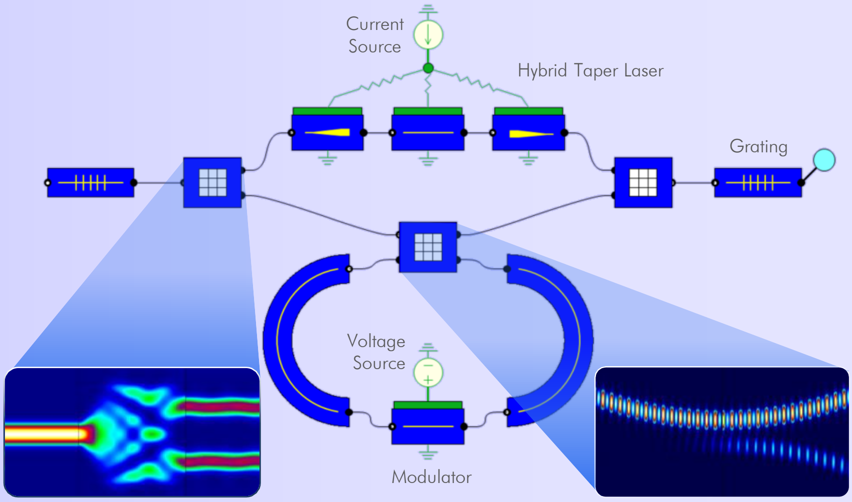
FIMMPROP features an advanced algorithm based on Rigorous Coupled Mode Theory (**RCMT**) for long shallow high index contrast gratings popular in SOI-based devices.

Image: Fiber Bragg grating as number of periods increased | **256 Results – 6.3s**

Include in Active Time Domain PICs

Supporting the full design flow, FIMMPROP can export rigorously simulated components to market-leading time domain circuit simulator **PICWave**. Connect wavelength dependent models of FIMMPROP components together with time evolving laser sources, modulators, and detectors, to simulate full photonic integrated circuits.

Common uses of FIMMPROP with PICWave
- Building PICs with directional couplers, MMIs, Y-splitters + more
- Finding kappa values for high contrast gratings (surface etch)
- Finding adiabatic taper lengths for ***hybrid lasers/ SOAs***
- Reflectivity of angled facets (for e.g. *SLEDs*)



MMI Coupler from FIMMPROP

Ring Coupler from FIMMPROP

The Natural Tool for Taper Simulations

FIMMPROP is ideal for designing continuously varying structures like tapered waveguides such as *hybrid laser cavities* and *fiber to chip couplers.*

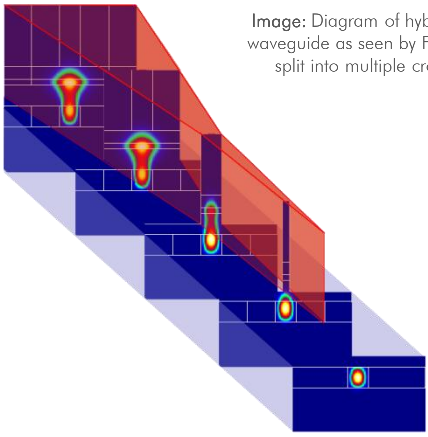
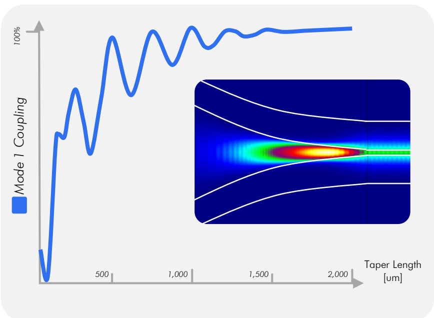


Image: Diagram of hybrid tapered waveguide as seen by FIMMPROP, split into multiple cross sections

Key Benefits

- FIMMPROP simulations are invariant with length so long tapers don't mean long compute times.
- Typically designed to operate near the adiabatic limit, only a modest number of modes are needed to accurately describe the propagating filed of an adiabatic taper.
- Photon Design have pioneered taper algorithms since 1998 with the most efficient method to describe continuously varying structures – ask our team how!
- Adiabatic length can be found quickly with FIMMPROP's native parameter sweep (see below).



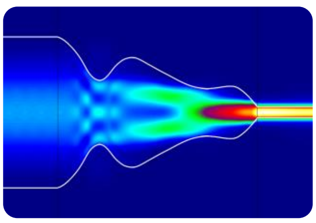
Instant Design Sweeps – Finding Adiabatic Tapers

Easily determine the adiabatic length of a taper design using FIMMPROP's convenient *in-built variable scanner*. When changes are made to a device, FIMMPROP will automatically recycle results from previous simulations; when *all* cross sections are unaltered, such as increasing a device length, all previous calculations are reused, fuelling blisteringly fast iterative design.

One FIMMPROP simulation of a taper provides the results at <u>all</u> lengths

Image: Native FIMMPROP scan of tapering fiber's length + field profile at length 10 mm.
First Simulation – 5.0s | **128 Results – 14.6s**

Automatic Optimisation with Kallistos



Photon Design's optimiser Kallistos thrives with fast frequency domain methods like FIMMPROP, allowing far more iterations to be performed on a more focused simulation achieving ***inverse design*** - like results.

Image: 7um long taper optimised with transmission improved from 54% (linear taper) to 92% with a geometry found by Kallistos.

Other applications of Kallistos :
- Minimise losses along a bend by providing Kallistos with parameters that define path and waveguide width.
- Position and scale MMI length and output waveguides to create splitters or a wavelength demultiplexer.

Python Scripting

Control FIMMPROP via the client server interface. This allows scripting with Python, MATLAB, C++, and more to pilot FIMMPROP.

Features:
- Building entire devices from commands
- Easier compatibility with other tools
- Performing multi-variable scans (testing error tolerance for example)
- Full native Python object model

Platforms

Platforms: Windows 10/11, 8GB RAM, 64-bit CPU, 4-core or better recommended (CPU multi threading is supported).
Mac + Linux: FIMMPROP will run on virtual machines to allow non windows machines to use the software. Ask our team for more information regarding this and remote access.

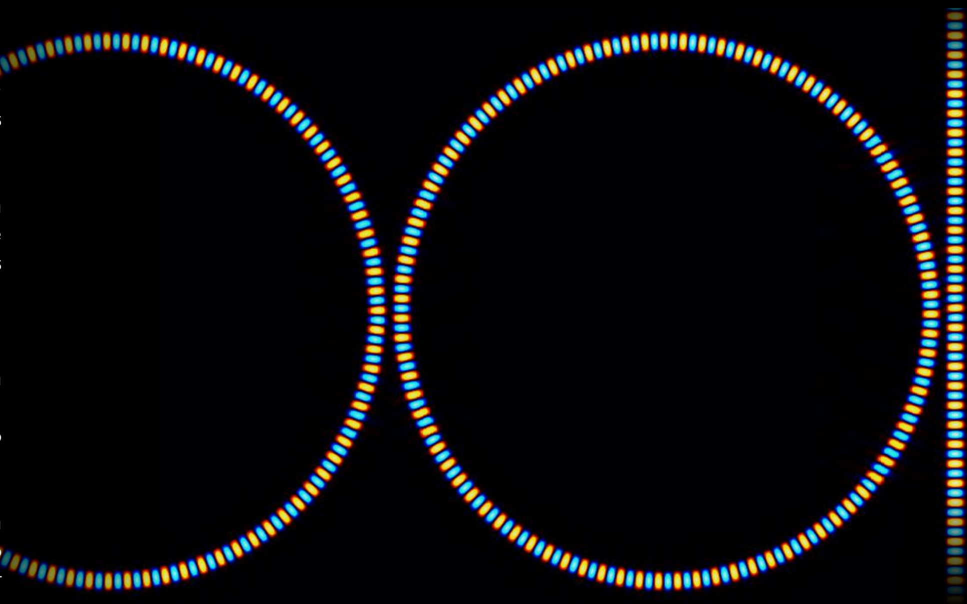
3 Essential Tools in a Single Environment

Component Design + Circuit Simulation + Layout

Mutli-Topology (MT)-FIMMPROP connects together 3D component simulations, expanding EME to the much larger, circuit level design. This makes FIMMPROP the first EME to offer a full ring resonator simulation performed natively as well as simulating large cascaded MZIs and centimeter length delay lines. After the full design is done, export a full device to GDS-II with one button.

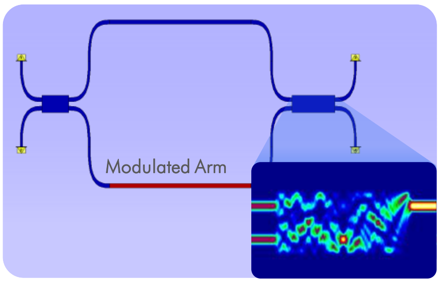
3D Ring Resonator Simulated in Seconds

- Repeated regions are reused to ***cut simulation time***. This 30 um radius ring simulation speeds up by ~5 times by exploiting design symmetry.
- Simulate what matters: Unlike FDTD which simulates a full bounding box (including the empty ring centres), MT-FIMMPROP simulates only along the waveguide paths + coupling regions.
- Coupling regions are described efficiently with FIMMPROP's advanced propagation algorithm. Straight and bend sections contribute next to no additional simulation time.
- Investigate important resonant frequencies with fast single wavelength simulations or choose to find full wavelength response using parameter sweeps.



Optional add-on to FIMMPROP. See MT-FIMMPROP brochure for more

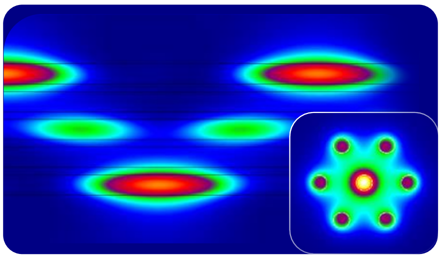
Further Applications



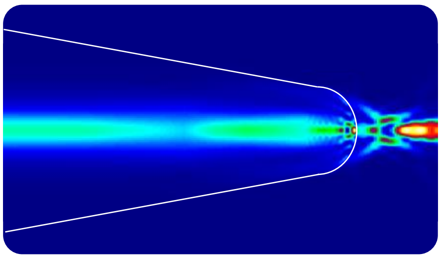
Full 3D MZM with X-Cut Thin Film Lithium Niobate

Combine rigorous simulations of Y-Splitters, Euler bends, and MMIs to create a full Mach-Zehnder interferometer simulation while simultaneously building your full layout. Combined with FIMMWAVE's ***electro-optic solver,*** calculate the effect of applied voltage on one 'arm' to simulate a full switch as shown in this example made in X-Cut thin film lithium niobate. Similar effects possible with thermal tuning with FIMMWAVE's thermal solvers.

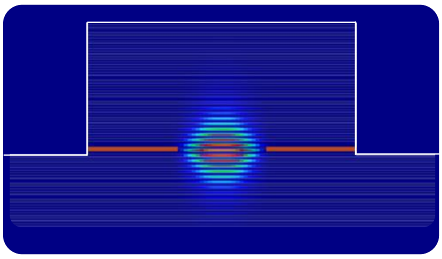
X-Cut Lithium Niobate: Ask our team how FIMMPROP will natively compensate for anisotropy.



Multi Core Fiber – centimetres or metres simulated in seconds. Find coupling lengths and decoupling distances in multi-core fiber geometries including bends.



Lensed Fiber – Supporting free space propagation through fibre-to-chip gaps, FIMMPROP deploys a unique algorithm developed by Photon Design. This is substantially faster than FDTD, BPM or even standard EME.



Cavity Modes – Full cavity modes can also be found with a bespoke 3D cavity mode calculator (able to simulate DBRs and even 3D VCSELs).

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