PRODUCT BROCHURE

Design of Integrated Photonic Devices & Optical Fibers

Photonic Device and Fiber Simulation

KEYSIGHT

Design of Integrated Photonic Devices & Optical Fibers

Keysight Photonic Device and Fiber Simulation (VPIdeviceDesigner) is a versatile simulation framework for the analysis and optimization of integrated photonic devices, waveguides, and optical fibers.

This powerful design tool offers a set of full-vectorial and semi-vectorial finite-difference mode solvers for waveguide analysis as well as a Beam Propagation Method (BPM) and an Eigenmode Expansion Method (EME) for simulating 2D and 3D photonic devices.

VPIdeviceDesigner supports the flexible definition of 2D waveguide cross-sections and 3D device layouts with realistic (dispersive, temperature-dependent, etc.) optical materials, widely customizable nonuniform meshing, and perfectly matched layers.

An advanced analysis of the simulation results, including manipulations on the calculated electromagnetic fields, and easy design automation concerning any desired performance criteria are facilitated.

VPIdeviceDesigner provides a user-friendly object-oriented Python interface, which is closely integrated with the Python-based ecosystem of open-source software for mathematics, science, and engineering, including the libraries NumPy, SciPy, and the comprehensive 2D plotting library Matplotlib. Besides, *VPIdeviceDesigner* facilitates the easy creation of compact simulation models for the designed waveguides and devices, enabling seamless integration with Keysight Photonic Integrated Circuit Simulation (VPIcomponentMaker Photonic Circuits) and Photonic Foundry PDK Library (VPItoolkit PDK <fab>) extensions.

Benefits

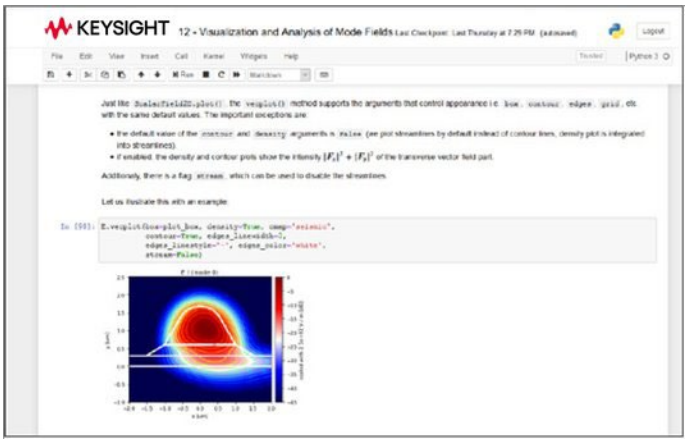


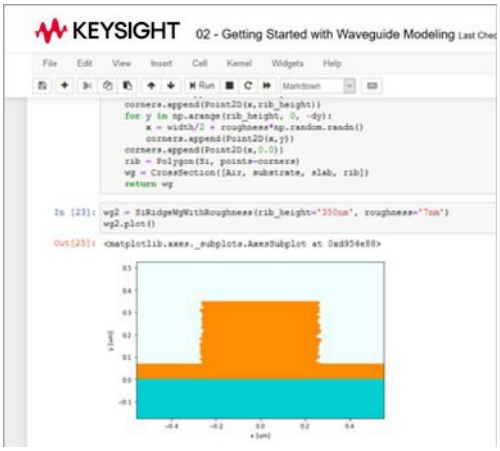
Figure 1. Jupyter Notebook environment of VPIdeviceDesigner

- Facilitate advanced waveguide layout definitions and optimization tasks via a powerful Python interface

- Model straight and bent waveguides and fibers made of dispersive, anisotropic, and lossy materials
- Model multi-mode, multi-core, and photonic crystal optical fibers
- Model uni- and bidirectional electromagnetic field propagation and scattering matrices for 2D and 3D photonic devices
- Verify cross-sections and device layouts and analyze results using advanced and highly customizable visualization capabilities
- Integrate with the circuit-level simulator VPIcomponentMaker Photonic Circuits

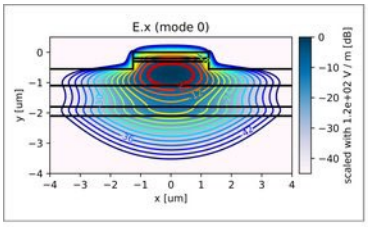
Features

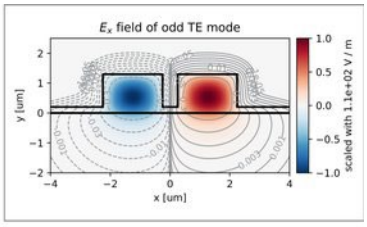
Powerful Object-Oriented Python Interface

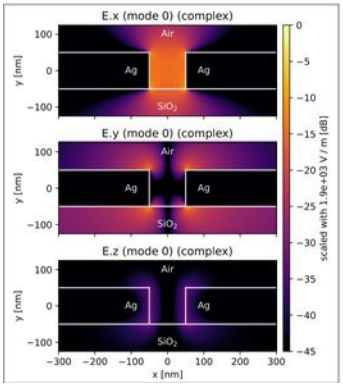


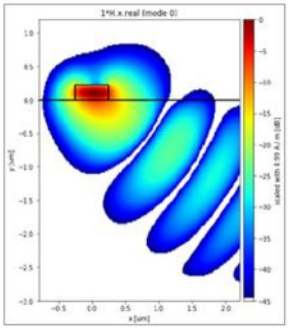
- Python provides easy to learn and feature-rich object-oriented programming environment
- User-friendly Jupyter Notebook environment allows combining interactive simulation scripts with results, figures, problem descriptions, and equations
- Integration with the SciPy ecosystem of Python open-source libraries enables advanced visualization and mathematical, scientific, and engineering computations

Finite-Difference Optical Mode Solvers



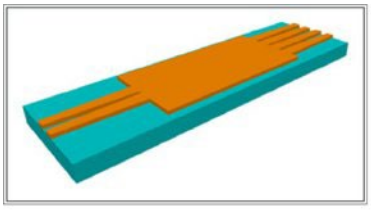


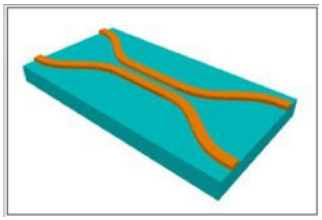




- Full-vectorial and semi-vectorial finite-difference 2D mode solvers for straight and bent anisotropic and isotropic channel waveguides and fibers
- Specialized finite-difference 1D mode solvers for straight and bent planar waveguides
- Support of nondiagonal anisotropy for straight waveguides
- Handling of electric field singularities near sharp corners of plasmonic and high-index contrast waveguides
- Calculation of guided and leaky modes (leakage to substrate, leakage due to bending)
- Support of Perfectly Matched Layer (PML) boundaries
- Symmetric perfect electric or magnetic conductor (PEC, PMC) boundary conditions

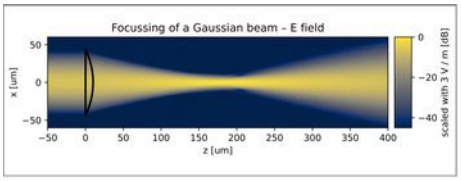
BPM and EME Solvers for Modeling Photonic Devices

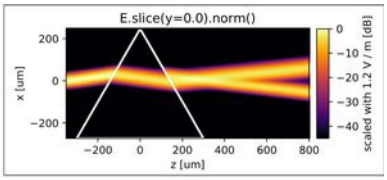


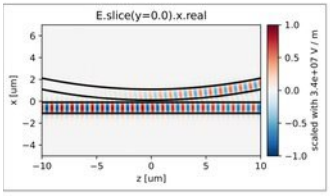


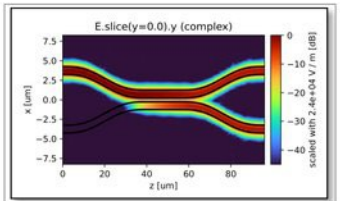
- Calculation of electromagnetic field propagation in 2D and 3D photonic devices
- Extraction of scattering matrices for multi-port photonic devices
- Support of arbitrary excitation sources:
  - Port modes and their superpositions
  - Gaussian beams
  - User-defined fields

Beam Propagation Method (BPM)



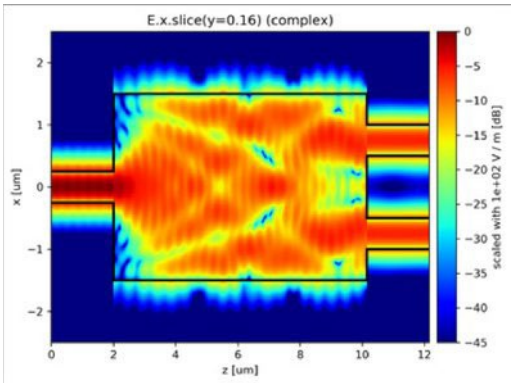






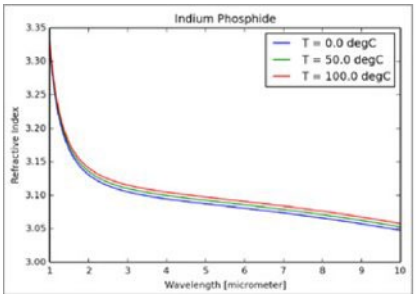
- Full-vectorial and semi-vectorial finite-difference 2D and 3D BPM schemes
- Uni-directional field propagation
- Paraxial and wide-angle approximations
- Absorbing PMLs and transparent boundary conditions
- Efficient for devices with low refractive index contrast and smoothly varying cross-sections
- Application examples: tapers, S-bends, directional couplers, ring couplers, Y-splitters

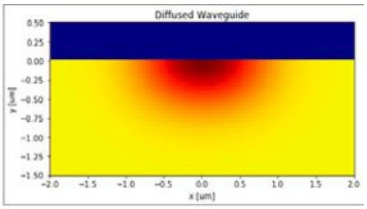
Eigenmode Expansion (EME) Method



- Based on full-vectorial finite-difference mode solvers
- Bi-directional field propagation handling back reflections
- Efficient for device length optimization, devices with high refractive index contrast and step-like varying cross-sections
- Application examples: Multi-Mode Interference (MMI) couplers and reflectors, polarization and mode convertors, edge couplers, and Bragg gratings

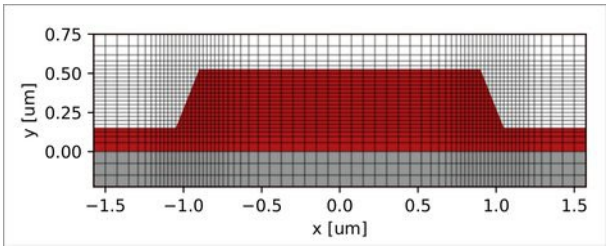
Dispersive, Lossy, and Anisotropic Optical Materials





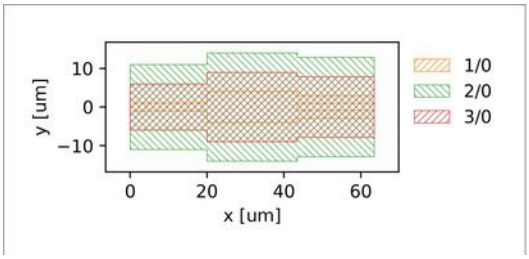
- Single-line definition of dispersionless lossy optical materials
- Native support of Sellmeier, Lorentz–Drude, Tauc–Lorentz, and Cody–Lorentz models models of dispersive materials
- Arbitrary frequency dependence of complex refractive index
- Anisotropic optical materials (including gyrotropic birefringence and magneto-optic effect)
- Custom inhomogeneous materials for graded-index fibers and diffused waveguides
- Library of predefined dispersive and thermo-optic materials (Air, Silicon, Silica, Si3N4, InP, LiNbO3, and standard metals)

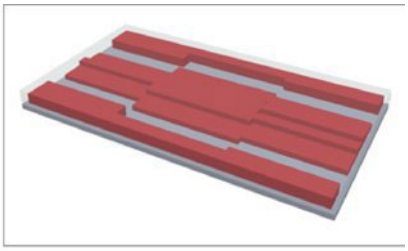
Customizable Nonuniform Finite-Difference Meshing



- Built-in adaptive quasi-uniform mesh
- Uniform, quasi-uniform, and stretched meshes in user-defined layout areas
- Arbitrary user-defined nonuniform meshes
- Sub-pixel averaging of discretized dielectric constant

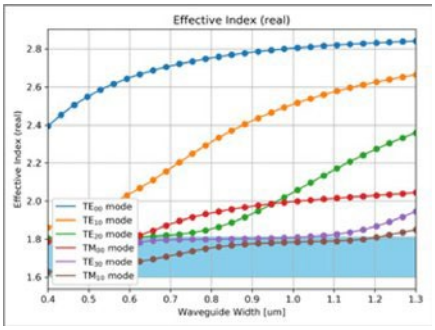
Flexible Layout Generation





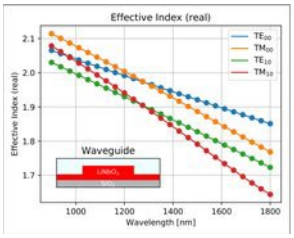
- GDS mask import and export
  - Extrude complete 3D layered components from imported GDS masks
  - Extract 2D etch masks from designed and optimized 3D layouts
  - Support of fabrication-aware corrections for sidewall angles, expansion or shrinkage, and inversion
  - Powerful filtering and transformation of points, enabling geometry sweeps on GDS-imported layouts
- Creation of 3D waveguides, tapers, S-bends, etc. from 2D waveguide cross-sections
- Built-in 2D and 3D geometry library for primitive shapes, geometrical transformations, and Boolean operations

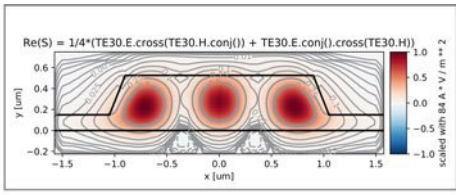
Parametric Modeling with Automated Sweeps



- Easy sweeping of wavelength and one more arbitrary model parameter (e.g., waveguide width, bend radius, mesh resolution, or refractive index)
- Flexible interface for calculating additional user-defined mode properties during sweeps
- Automated fitting or interpolation of sweep results
- Plotting a mode property vs. the sweep parameter is easy—correct axis labels and legend entries are created automatically

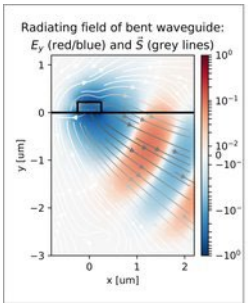
Mode Properties Analysis

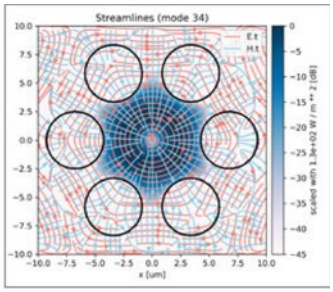




- Immediate access to dispersive waveguide properties (group mode index, group velocity dispersion, and dispersion slope) as well as mode attenuation, custom user-defined properties, and vectorial mode fields
- Easy calculation of mode expansion coefficients, mode overlap integrals, optical coupling efficiency, mode power, and other characteristics
- Electric and magnetic fields are Python objects natively supporting mathematical operations such as field superposition and scaling, scalar and vector products, etc.

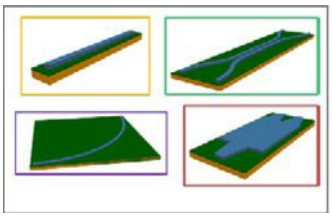
Advanced Plotting Capabilities





- Built-in field interpolation and visualization
- Single-line plot methods for a quick overview of results
- Highly configurable field plots supporting field lines, contour lines, density plots, etc.
- Access to underlying Matplotlib objects for additional plot customization

Interoperability and Data Export

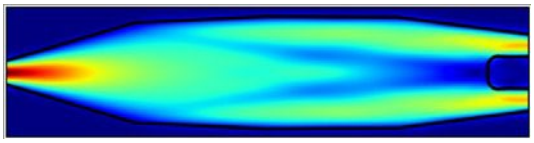




- Export guided mode properties and device scattering matrices for use in VPIcomponentMaker Photonic Circuits
- Save your results (guided modes and fields) to reuse them later without recalculation
- Utilize Python's power and flexibility to post-process and export results for the desired target application

Application Examples

Y-Splitter



The beam propagation method is ideally suited for long slowly varying photonic devices such as this Y-splitter.

With *VPIdeviceDesigner*, you can calculate the fields, optimize the transmission, and export the device S-matrix to integrate the optimized design into a photonic circuit simulation.

Polarization Converter

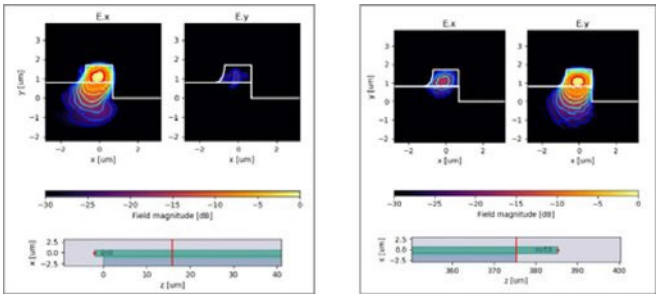
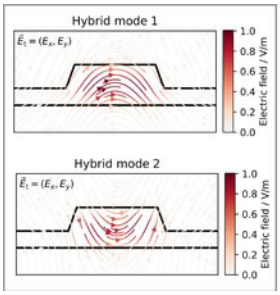
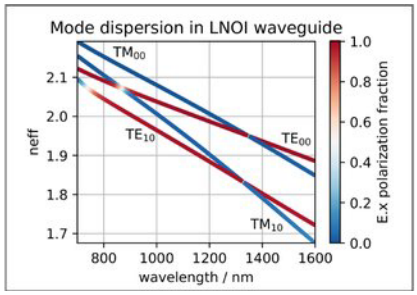


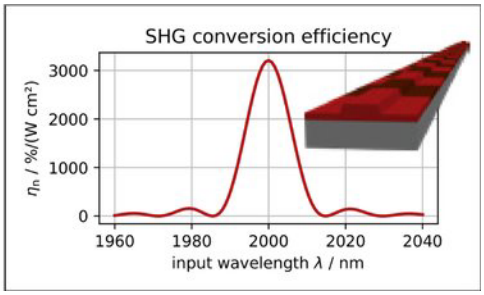
Figure 2. Input and Output mode profiles of the Polarization Converter

The shown indium phosphite-based waveguide utilizes its asymmetry to rotate an incident x-polarized mode field into a y-polarized field. In *VPIdeviceDesigner*, this device can be analyzed and optimized by combining mode solver results with either BPM or EME.

LNOI Waveguide

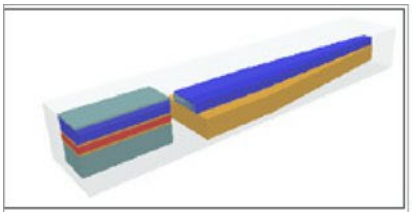


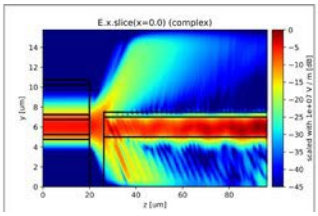


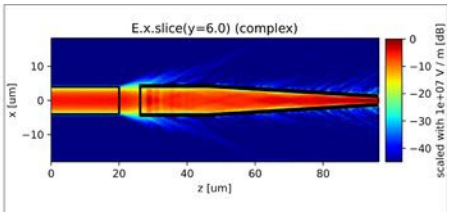


With *VPIdeviceDesigner* you can perform arbitrarily complex analysis of the properties of waveguides and fibers. Built-in calculation of effective and group mode indices, mode polarization fractions, and other characteristics allow, e.g., to analyze mode hybridization and avoided mode crossings in an anisotropic LiNbO3 waveguide. Advanced post-processing capabilities enable, e.g., the calculation of second-harmonic generation efficiency, poling period, and bandwidth characteristics of PPLN waveguides.

Edge Coupler

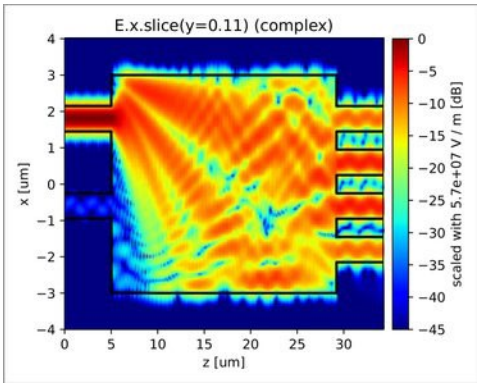






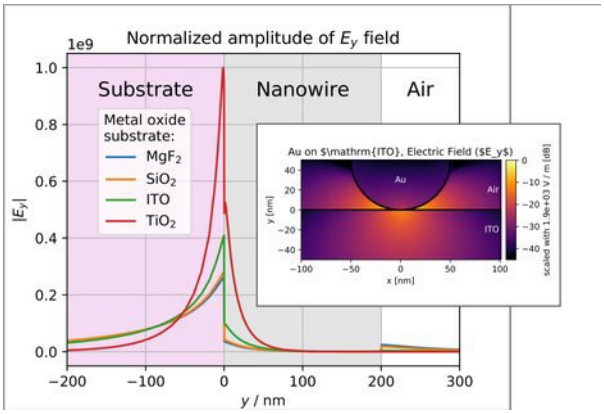
When different semiconductor technologies are combined, light needs to be coupled from one chip to another. In this example, a quantum-cascade laser and a germanium-based waveguide are coupled, followed by a taper to ensure single-mode operation. With *VPIdeviceDesigner*, you can optimize the input waveguide cross-section and investigate the influence of the air gap between the chips on the transmission.

Optical 90° Hybrid Coupler



Multi-Mode Interference (MMI) devices can be efficiently optimized for the required S-matrix properties by using the EME solver. This example shows a 2×4 MMI optimized to work as an optical 90° hybrid coupler.

Circular Plasmonic Nanowire



VPIdeviceDesigner's full-vectorial mode solvers accurately calculate not only modes in dielectric waveguides but also plasmonic modes with strong field confinement. The example shows a plasmonic mode's field distribution for an Au nanowire on an ITO substrate and the field enhancement for different metal oxide substrates.

As a mission-critical design enablement partner, Keysight connects design, emulation, and test so customers can solve the world's most complex engineering challenges. Accelerate innovation at www.keysight.com.

KEYSIGHT

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