

Computing Bending Modes

Products: FemSIM FEM

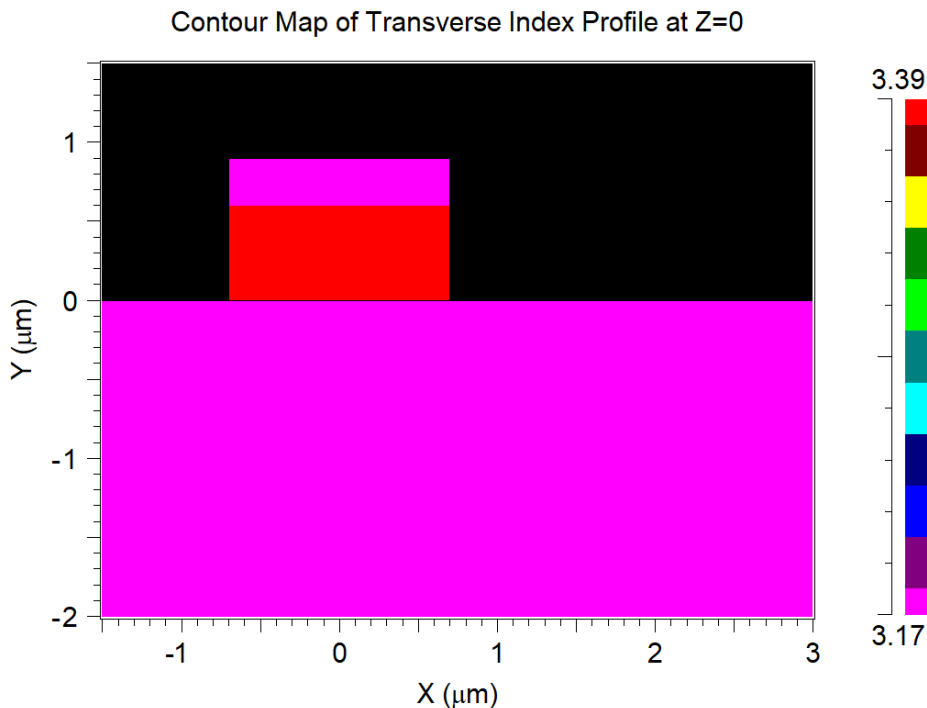
Applications: Waveguides and Fibers

Introduction

The calculation of bending waveguide modes is essential to the design of Planar Lightwave Circuits (PLCs) and other waveguide-based photonic devices. Bending waveguides introduce shifts in the mode shape and bending losses which, as a function of the waveguide radius, determine the minimum bending radius as well as the minimum size of the PLC. We will use a simulated bend in **FemSIM FEM** to calculate the bending mode.

Simulation of Bending Mode

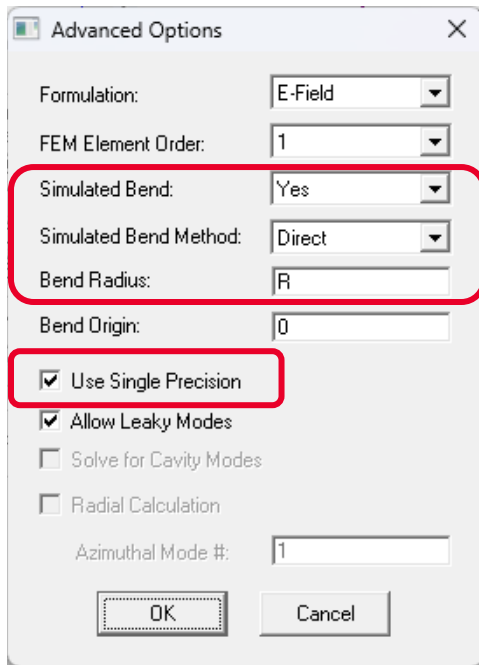
As an example, we will compute the fundamental bending mode of a simple ridge waveguide shown here. It has a width of $1.4\text{ }\mu\text{m}$ and consists of an InGaAsP guiding layer ($n = 3.39$) and an InP cap layer and substrate ($n = 3.17$). The operating wavelength is $1.55\text{ }\mu\text{m}$.



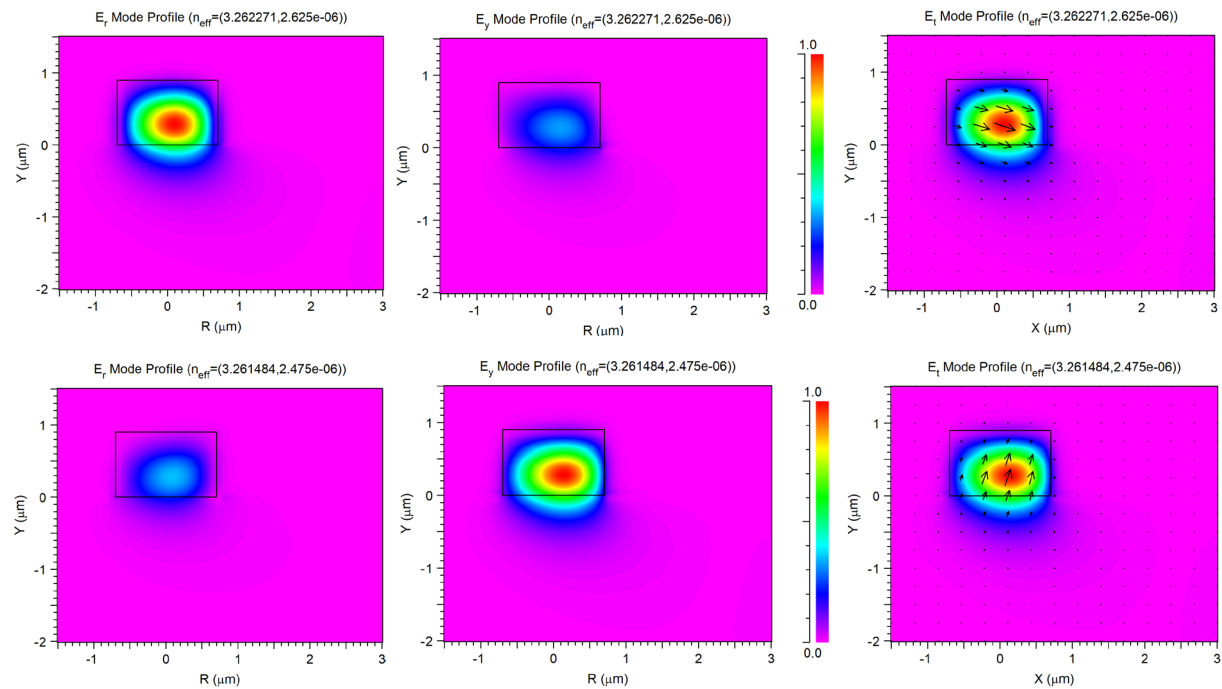
To enable the calculation of a bending mode, we need to make several settings in the FemSIM FEM Advanced Options dialog box:

- Simulated Bend: Yes
- Simulated Bend Method: Direct. This enables the use of a cylindrical form of Maxwell's equations to directly solve for bending modes.
- Bend Radius: R. This is a symbol we defined to represent the bending radius and has a value of $50\text{ }\mu\text{m}$.
- Allow Leaky Modes: selected, since bending modes are inherently leaky.

We also set a PML Width of 0.5 μm in the FemSIM FEM Simulation Parameters dialog.

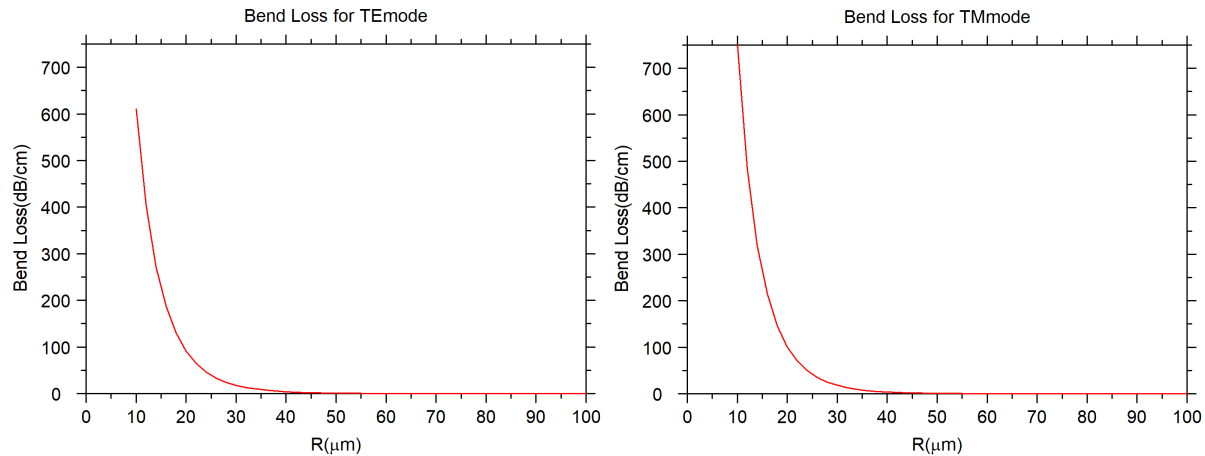


The calculated TE (top) and TM (bottom) fundamental bending modes are shown below. The E_x (left), E_y (center), and a vector plot of the transverse $\mathbf{E}$ field (right) are shown.



These leaky modes profiles are clearly shifted from the center of the guiding layer and the vector plot shows that the polarization has been slightly rotated. The TE bending mode has a modal effective index of $3.262271 + i2.625e-06$. The imaginary part of the effective index (n_i) is related to the loss as $54.5474 \cdot n_i / \lambda$. For this mode, the loss is 0.92dB/cm.

We can also study the loss vs radius using the MOST scanning tool. The results for the fundamental TE and TM modes are shown here:



Understanding the mode profiles and loss of bending modes is critical for designing PLCs. These types of modes can easily be computed using the simulated bend feature.

Conclusion

FemSIM FEM efficiently computes bending modes and associated losses in curved waveguides. By accurately capturing mode distortion, polarization rotation, and bend-induced loss, it helps designers optimize bend radii and reduce circuit size while maintaining performance. Combined with MOST parameter scanning, FemSIM FEM provides a practical solution for developing compact, low-loss PLCs and other waveguide-based photonic devices.

Example files

Computing Bending Modes

References

Keysight Optical Solutions FemSIM FEM User Guide

- FemSIM FEM Simulation » 5 Advanced Tutorials » Tutorial 4: Bending Modes



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.

This information is subject to change without notice. © Keysight Technologies, 2026, Published in USA, August 12, 2026, 3126-1496.EN