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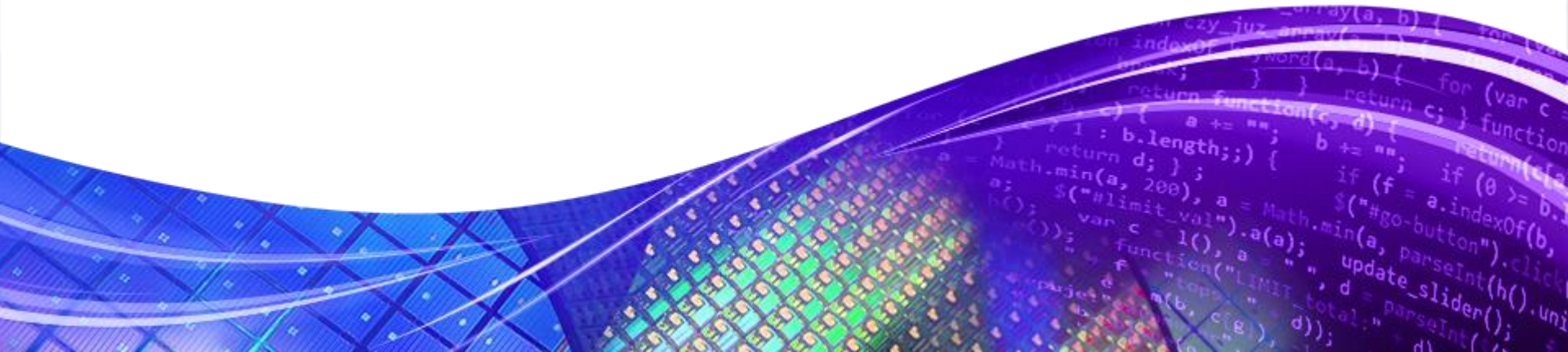
Reflective MMI



Outline

Introduction

Reflective MMI

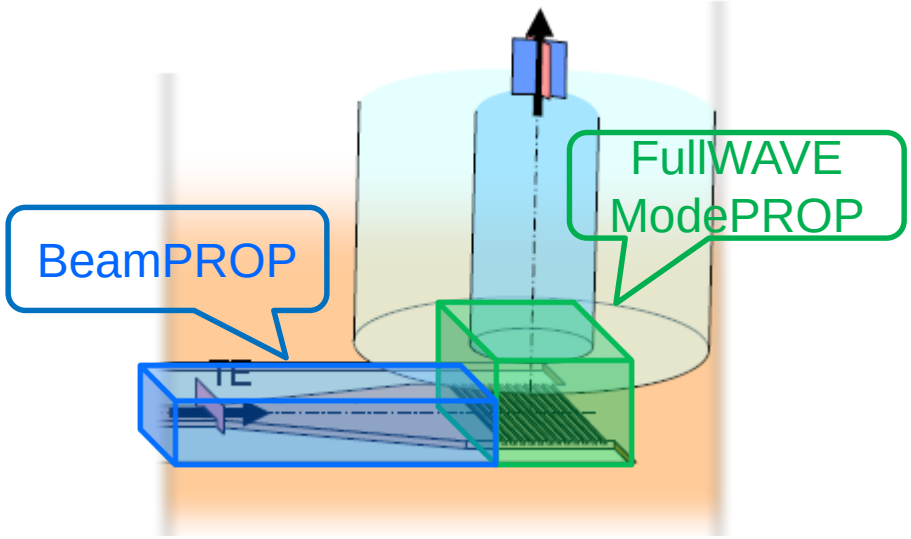
- **BeamPROP:** Forward and backward propagation
- **FullWAVE:** Reflective region simulation

Conclusions

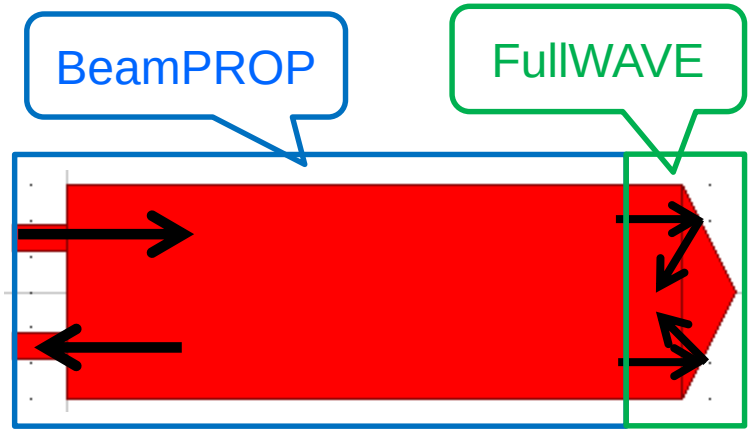
Introduction

- Synopsys RSoft Device tools provide a wide spectrum of photonics component simulation software, each solving a specific kind of problems
- Many problems are too big or too complex to be simulated by a single tool
- They can be decomposed into a number of smaller problems and solved by different tools

Grating Fiber Coupler

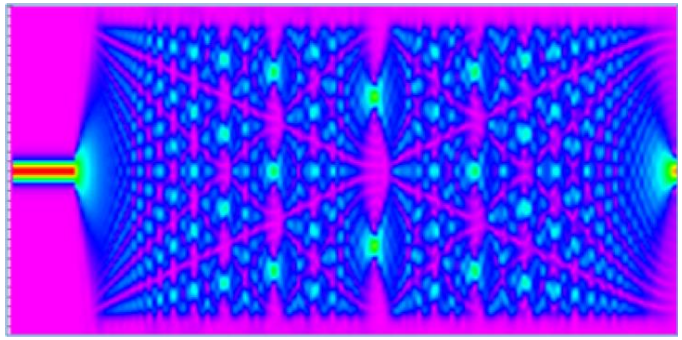


Reflective MMI

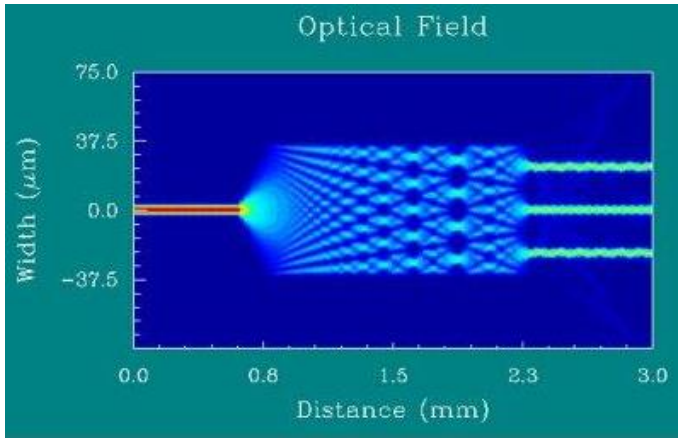


Reflective Multi-Mode Interference (MMI) Devices

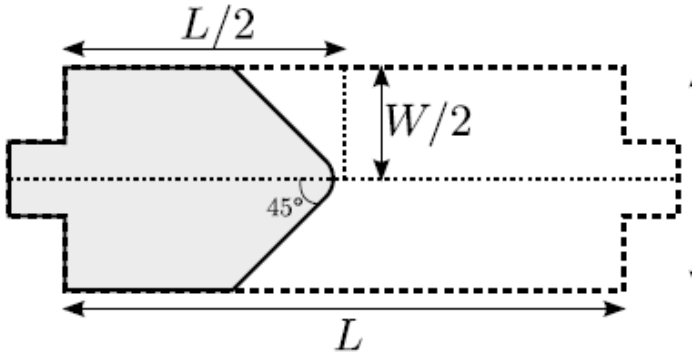
- MMIs are a common device in photonics integrated circuits (PICs)



- Conventional MMIs are usually very long, making integration onto a PIC difficult



- Reflective MMIs with etched TIR mirrors save space for integration



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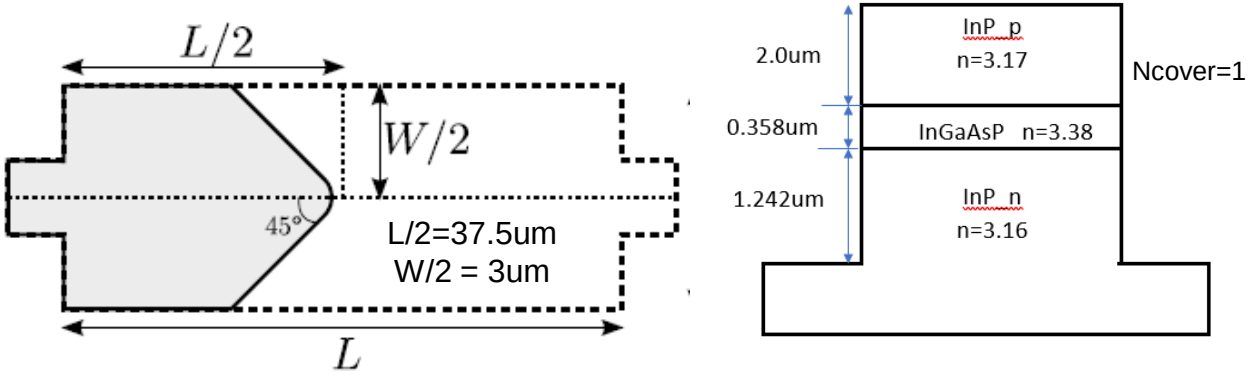
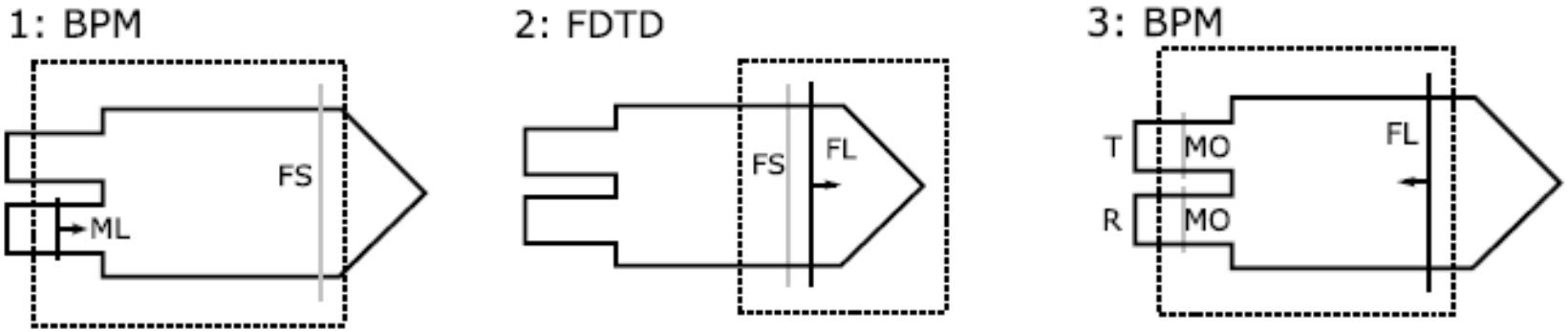
Combining BeamPROP and FullWAVE

- MMI structure is too big for FullWAVE, esp. for 3D
- BeamPROP cannot handle facet reflection
- Combining BeamPROP for the MMI region and FullWAVE for the facets is the best approach



MMI top view of MMI structure (left), cross-section (right)

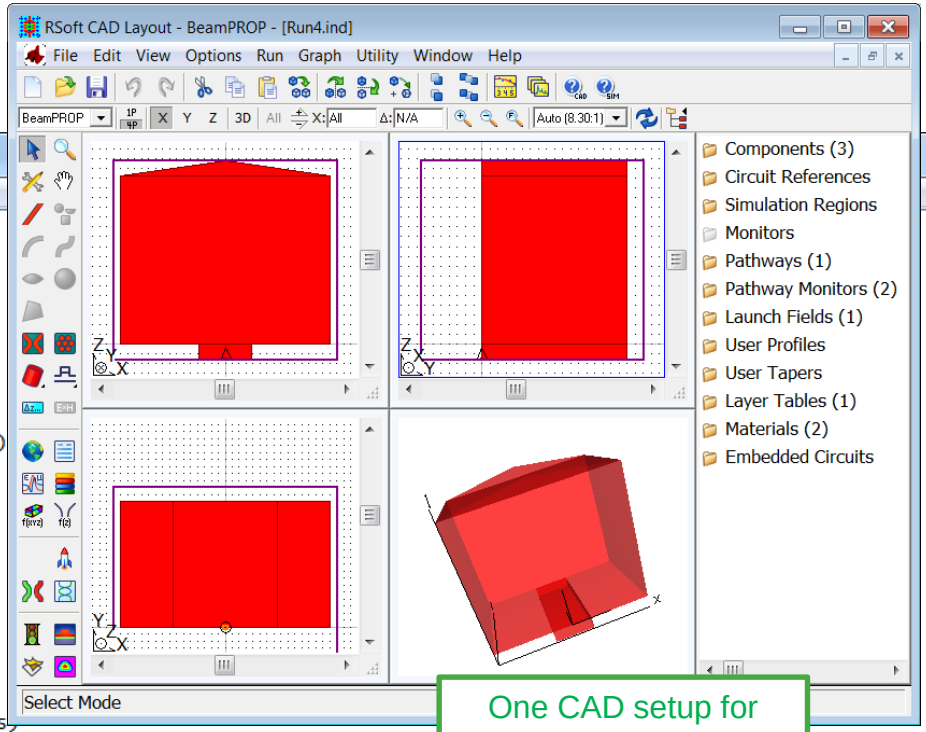


BP-FW Simulation methodology

Kleijn, Emil, Meint K. Smit, and Xaveer JM Leijtens. "Multimode interference reflectors: a new class of components for photonic integrated circuits." Lightwave Technology, Journal of 31.18 (2013): 3055-3063.

User-Simulator: Python Script

- A python script is written to automate the BP-FW-BP simulation flow

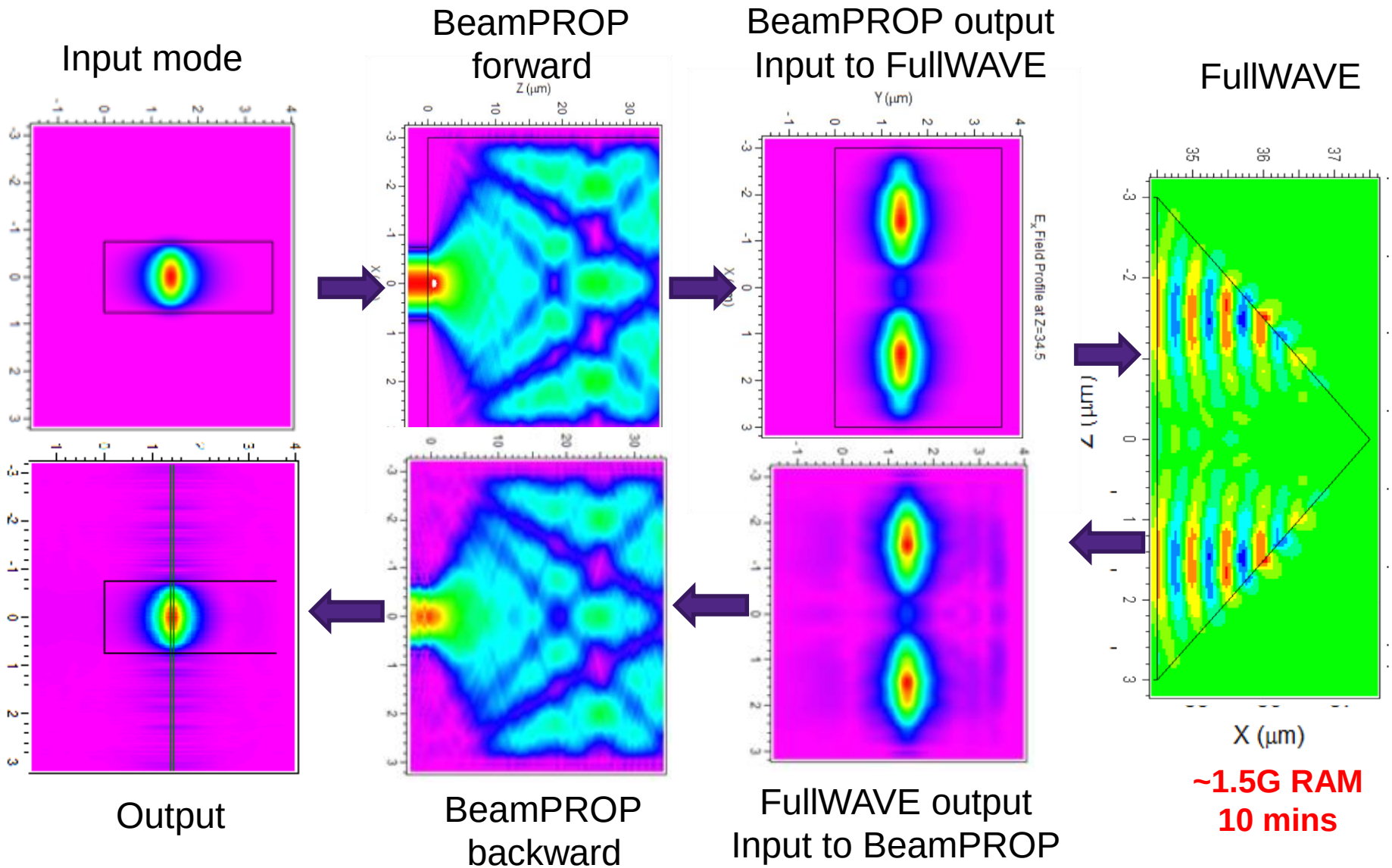


MMI_ref1.py - Notepad

File Edit Format View Help

```
# Import required libraries
import sys
import os
import rsoft.rspytools as rspy

# Parse standard user simulator command line into:
#   minusopts
#   indfile
#   symscmd
#   prefix
#   tail_args
(minusopts,indfile,symscmd,prefix,tail_args)=rspy.parse_usersim_args(sys.argv)

# Determine executable name of simulation tool depending on OS type
if os.name=='posix':
  sim_tool1='xbeam'
  sim_tool2='xfullwave'        #Linux
else:
  sim_tool1='bsimw32.exe'  #Windows
  sim_tool2='fullwave.exe'  #Windows
  sim_tool3='fwmpirun'  #Windows

# Build the basic command, without the prefix so we can override it later:
#   <sim_tool> <minusopts> <indfile> @<symsfile> <tail_args>
# All other commands will add additional arguments to the end of this command
base_cmd_BP='%s%s %s %s %s'%(sim_tool1, minusopts, indfile, symscmd, tail_args)
base_cmd_FW='%s%s %s %s %s'%(sim_tool2, minusopts, indfile, symscmd, tail_args)
base_cmd_FWcluster='%s%s %s %s %s'%(sim_tool3, minusopts, indfile, symscmd, tail_args)

0
# BPM mode calculation for input waveguide
cmd1='%s launch_type=LAUNCH_GAUSSIAN mode_set=0 launch_width=Win launch_height=H_InP_n+H_InGaAsP/2 Lin=1000 domain_max=0 domain_min=-1000 prefix=mode_BP'%(
rspy.spawn(cmd1)

1
# BPM simulation from input port to the end of MMI and store the results in <prefix>
cmd2='%s launch_file=mode_BP.m00 domain_max=L_MMI domain_min=-3 prefix=%s_BP1'%(base_cmd_BP,prefix)
rspy.spawn(cmd2)

2
# FDTD simulation for triangle section
cmd3='%s launch_file=%s_BP1_ex.fld domain_min=L_MMI-step_size*3 launch_position_z=L_MMI domain_max=L_MMI+Ltri+0.1 prefix=%s_FW'%(base_cmd_FWcluster,prefix,
rspy.spawn(cmd3)

3
# Backward BPM simulation from end of MMI to the beginning of input port and monitor the output overlap with input waveguide mode
cmd4='%s launch_file=%s_FW_bpm.dat bpm_backward_auto=1 domain_min=L_MMI-3*step_size domain_max=-3 prefix=%s_BP2'%(base_cmd_BP,prefix,prefix)
rspy.spawn(cmd4)
```

BeamPROP + FullWAVE Simulation



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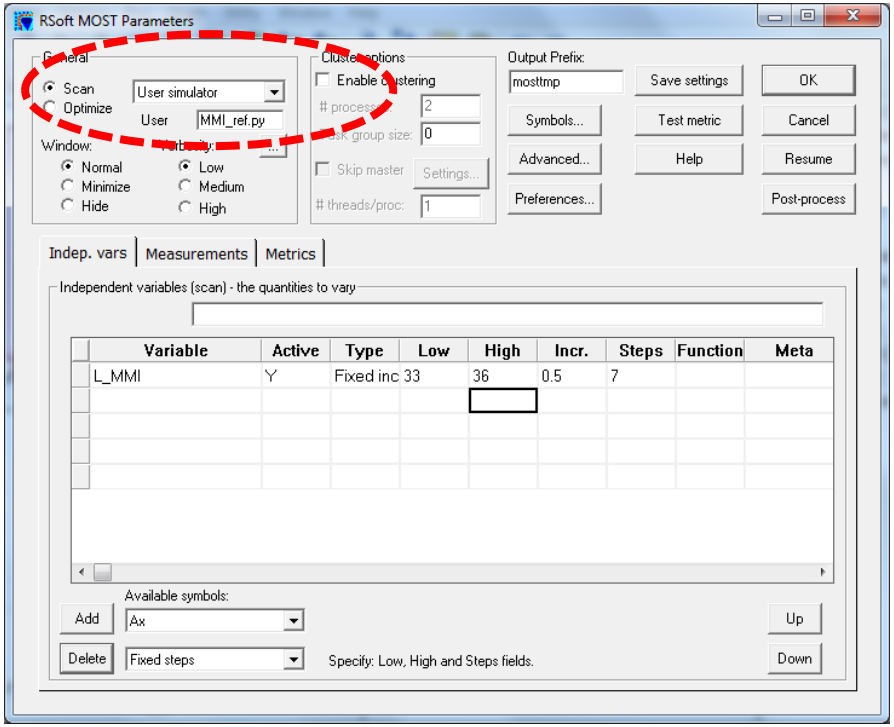
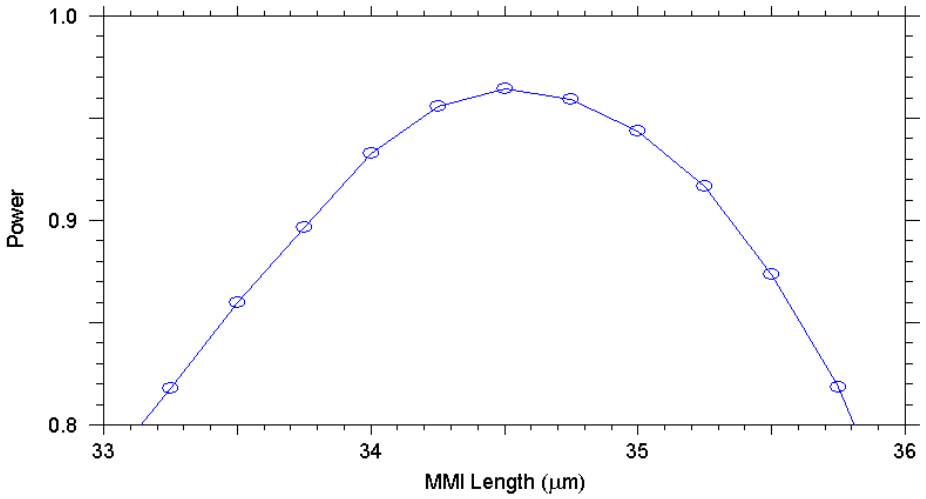
MOST Scan

- The output power vs. MMI length can be scanned using the MOST optimization and scanning tool





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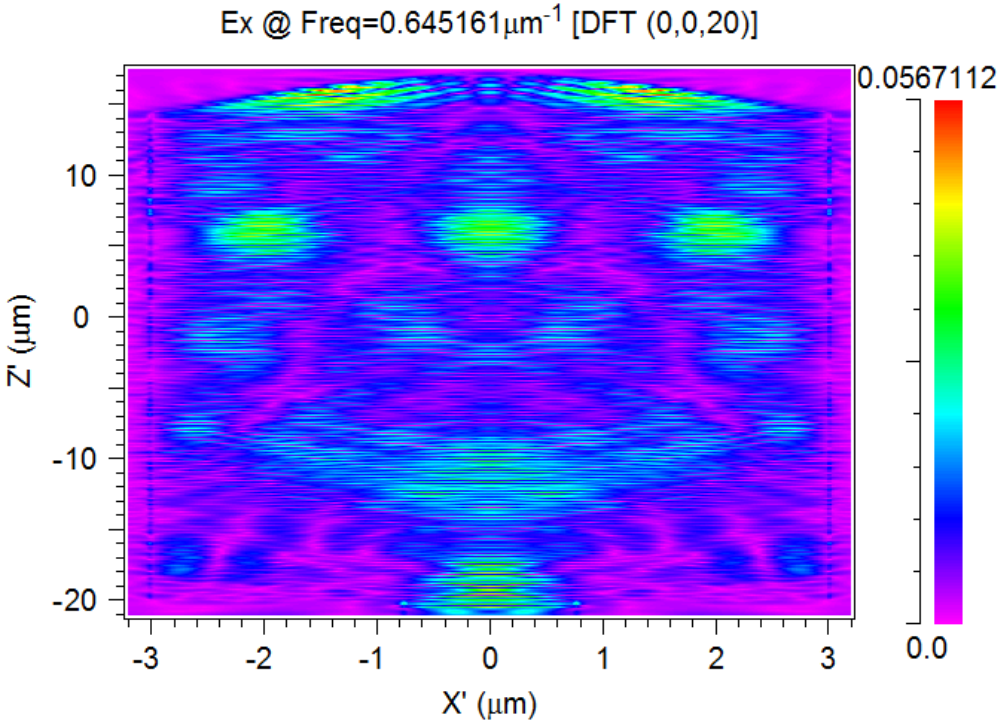
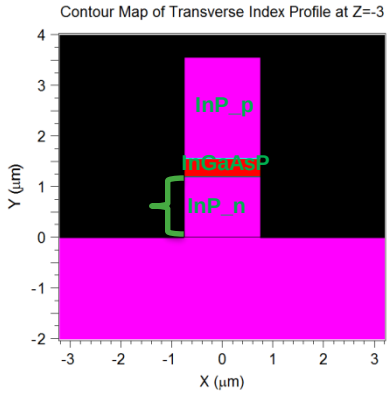
Comparing hybrid solution vs 100% FDTD Result

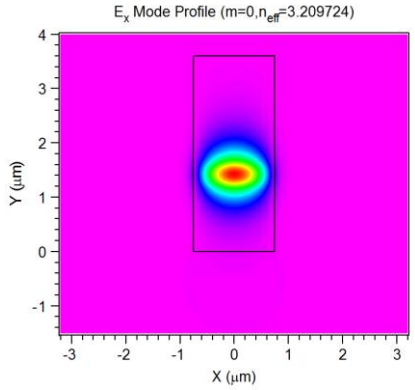
- FullWAVE can be used to simulate the entire structure.
- The results are similar, but takes about 20 hours on a 8-core computer with ~20G RAM for ONE simulation.

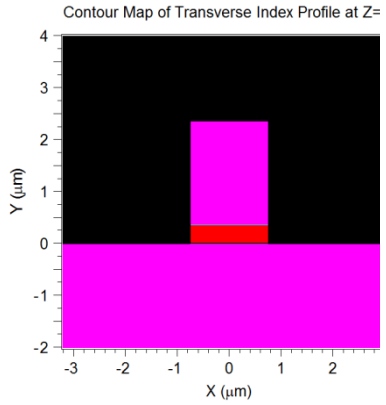


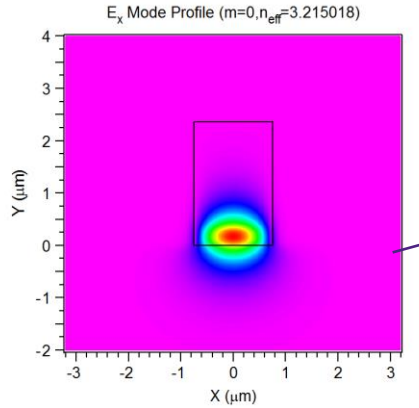
Sensitivity Study

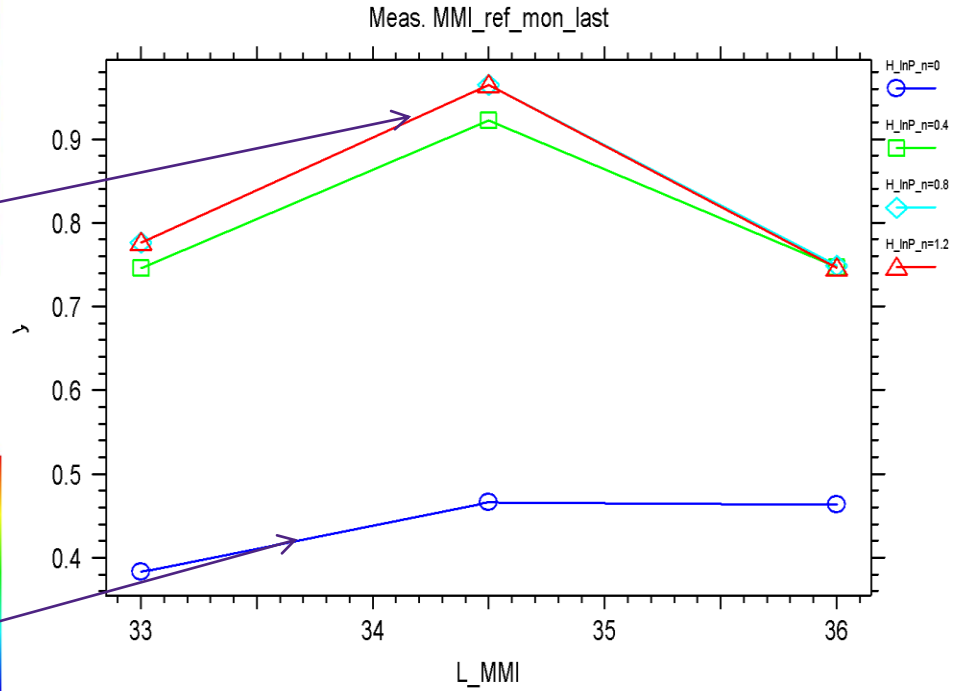
- Effect of etching depth (InP_n layer thickness) can be explored using MOST











Deep etched MMI works better!

Conclusions

- Synopsys provides a wide spectrum of photonic simulation software, covering devices, circuits, and systems
- Each simulation tool has its own application scope, comes with specific strength and weakness, and solves different problems
- A big and complex problem usually can be decomposed into a number of smaller and simpler problems
- Each smaller problem can be solved by a specific tool, whichever is more efficient and effective

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Thank You