

# Ansys Lumerical

**CYBERNET**

Since 1985

## Photonics Simulation & Design Software


 Computer Aided  
Engineering (CAE)

 Photonics,  
Optics & VR

 Engineering  
Services

CYBERNET MALAYSIA is a Channel  
Partner of Ansys in Malaysia,  
Indonesia, Myanmar, Philippines,  
Singapore, Thailand, and Vietnam.



Ansyes® Lumerical is a suite of photonic simulation tools that offer advanced features for designing and analyzing photonic components, devices, and systems. It can perform component level analysis using optical and electrical solvers, and address the most challenging design problems in Photonic Integrated Circuit (PIC) systems.

Application areas include  
Datacom, LiDAR, Quantum,  
PDK development, Sensing,  
Image Sensors, AR/VR, Display,  
Lighting, Metrology & defects.

## Product Values

- Component and system level simulation tools.
- Optimizes performance, minimizes physical prototyping costs, and reduces time-to-market.
- Enhanced design flows with compact models calibrated to leading foundry processes.
- Ansys works with leading technology partners to develop power electro-photonic workflow.

## Photonic Solvers

Photonic  
Multiphysics  
Simulator



FDTD



MODE



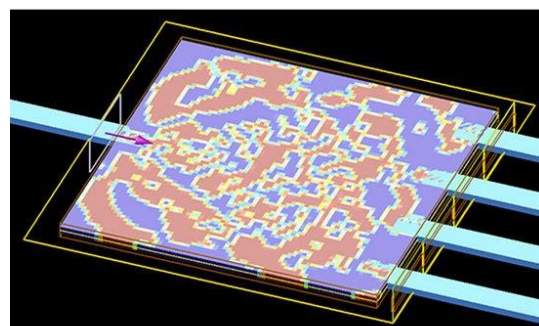
DEVICE



INTERCONNECT



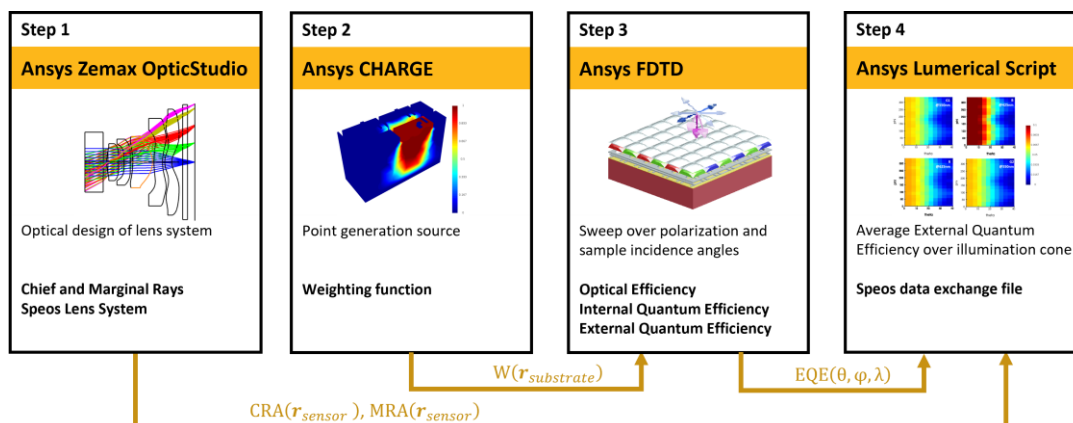
CML



Photonic  
Integrated  
Circuit (PIC)  
Simulator

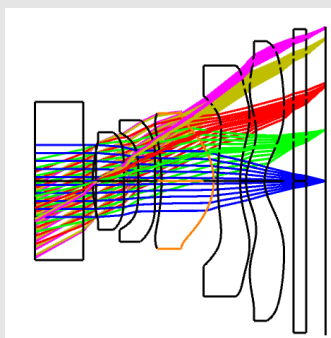
## CMOS Sensor Camera – Sensor Characterization

**Introduction:** This example introduces the CMOS image sensor (CIS) simulation workflow that involves 3D electrical and broadband optical simulations. This example considers both the azimuthal and polar angles of the incident light, allowing EQE extraction for further simulation in Speos® Sensor System (SSS) Exporter. This example is a realistic and versatile demonstration.

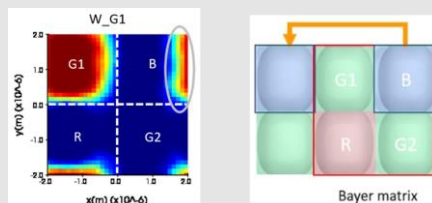


### Results

**Step 1:** lens system was designed in Zemax OpticStudio™ and extracted the marginal and chief ray angle (CRA & MRA) to define the illumination cone at different positions on the sensor plane.

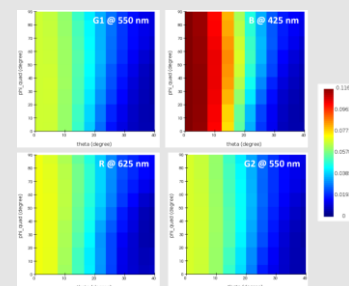


**Step 2:** a 3D charge transport simulation of a pixel and its neighbors is used to calculate the weighting function to get the probability of the charges generated at a given location in the substrate will be collected in the n-well of the pixel.

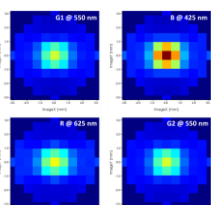


The main reason for the larger contribution from the B pixel to the left of the G1 pixel is that the doping distribution is not symmetric around the center of the pixel (the n-well is off-centered). Clearly, this is an important design consideration.

**Step 3:** calculate the optical efficiency (OE), IQE and EQE as functions of incident angle and functions of pixel type.



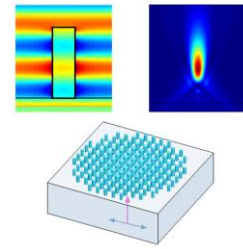
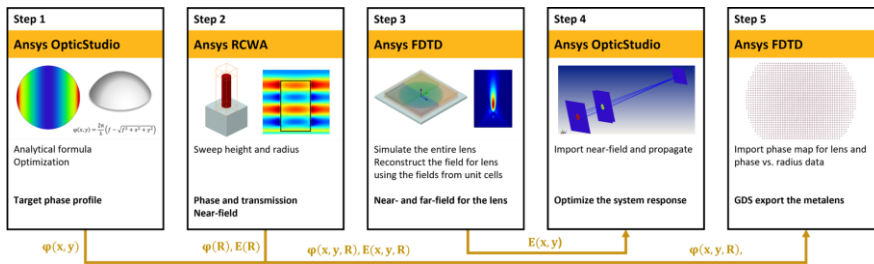
The higher overall EQE in the blue pixel compared to other pixels is mainly due to the higher absorption coefficient of the silicon at shorter wavelengths. Compared to green and red light, the concentration of charges generated by blue light is higher and more confined close to the silicon surface.



**Step 4:** the efficiency data from each simulation is consolidated in a single MATLAB® data file and averaged over polarization to describe unpolarized light. Users only interested in the angular dependence of the EQE can stop at this point. The IQE and EQE at given sensor positions are determined by averaging over the illumination cone specified in the JSON ray file from Zemax OpticStudio. The averaging is done in two steps. First, the efficiencies at the CRA and MRA for each sensor position in the JSON ray file are calculated by linear interpolation from the angular data. Second, a weighted sum of the EQE for the CRA and MRA is calculated at each sensor position using the product of Weight and Intensity from the JSON ray file as the weighting factor for each ray angle.

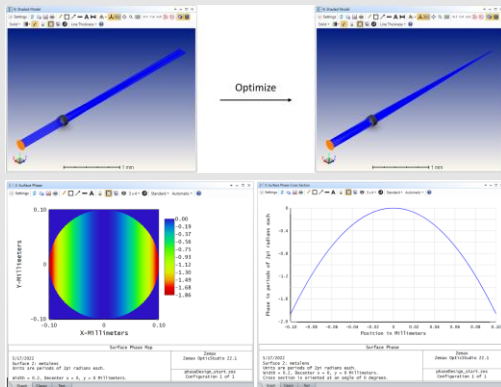
## Small-Scale Metalens – Field Propagation

**Introduction:** This example shows the workflow to design a diffractive metalens consisting of cylindrical nanorods. The radius and the arrangement of the nanorods are tailored to create a desired phase profile on the metalens surface.

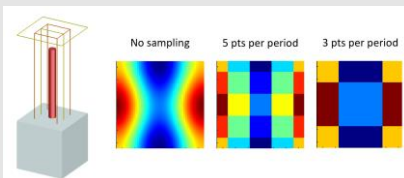


### Results

**Step 1:** define the target phase profile for the metalens. For the most common lens types, such as spherical or cylindrical elements, we can use the known analytical solutions. However, we can design the ideal phase mask in OpticStudio using ray tracing and optimization capabilities for more complex systems where analytical solutions don't exist or would be hard to calculate.

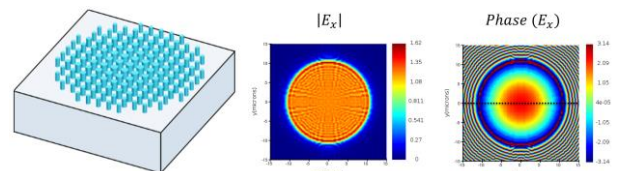


**Step 2:** we sweep the height and radius of the nanorod and obtain the transmission, phase, and near-field. The height that gives the desired transmission and phase properties is chosen. The phase and field vs. radius results are then saved for the next steps.

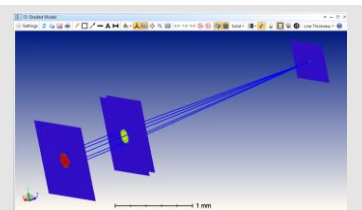


**Step 3:** once the library of phase/field vs. radius is built from step 2, there are two approaches available for the design and analysis of the full metalens.

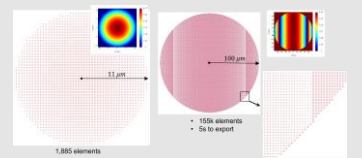
**Direct simulations:** Construct and simulate the full metalens in FDTD based on the target phase profile and the phase vs. radius data from the previous step. While this approach is more straightforward, it can pose challenges in terms of memory and simulation time, especially for larger metalens. The nearfield from the simulation can be used for far-field analysis and exported to a .ZBF file for further propagation in the Ansys OpticStudio.



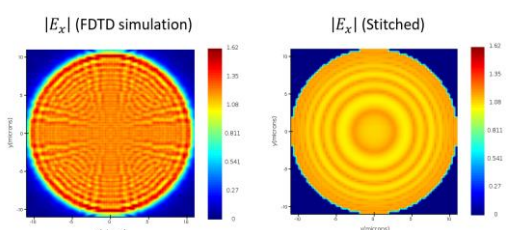
**Step 4:** simulate the propagation of imported beam in OpticStudio to re-optimize the system response.



**Step 5:** export the pattern in GDS format for fabrication purpose.



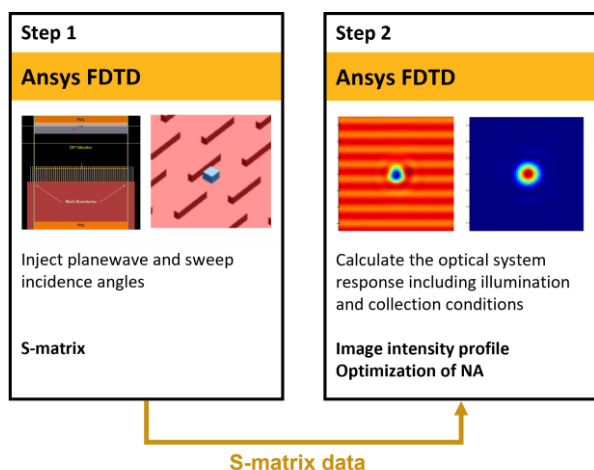
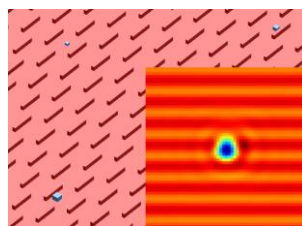
**Reconstruction of full fields:** The near-field/far-field of the full metalens can be reconstructed with a script using the nearfield library (Step 2). This avoids the time-consuming simulation of the full lens hence much more efficient than the direct simulation approach. A detailed description of these approaches is provided in the corresponding step in the "Run and Results" section. We will use a spherical metalens with a small radius to verify the accuracy of the "indirect" approach. Then, the approach will be applied to a much larger metalens based on the optimized target phase in OpticStudio.



## Optical Defect Metrology (S-Matrix)

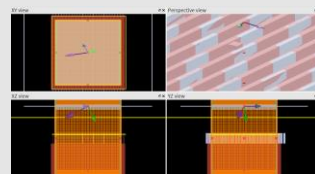
### Introduction

This example shows the simulations of defects on wafers in optical inspection systems in FDTD. Images generated by a UV scanning spot microscope are simulated to detect the presence of defects. The system performance is optimized by representing the illumination and collection paths as optical transfer functions and combining them with S-matrix in post-processing.



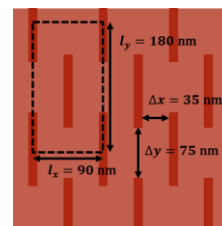
### Results

**Step 1:** to obtain the response of the structure for plane waves with a set of injection angles. The results (again, a set of planewaves) together with input planewaves form an S-matrix relating the input and output states. Since arbitrary beams can be decomposed into planewaves, the S-matrix provides a means to calculate the response of the structure to an arbitrary input beam, without directly running the simulation.



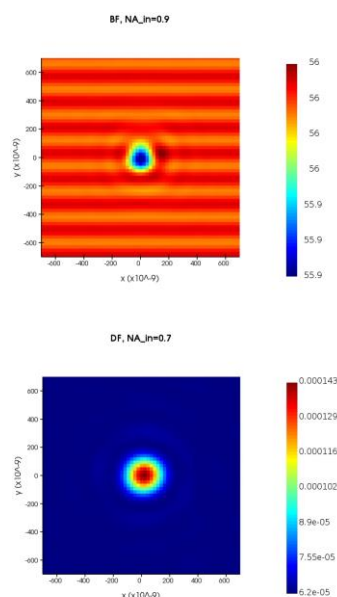
Calculate the optical transfer functions (OTFs) of the illumination and collection optics. The OTFs together with the S-matrix allow the calculation of the images expected for the imaging system under consideration. Unless the wavelength or the structure (including the defects) is modified, the same S-matrix can be used to calculate the responses for different illumination/collection configurations.

The simulated SRAM (static random-access memory) structure is composed of interleaved rectangles arranged periodically on top of a substrate; the material for both is silicon ( $n=3.6$ ). We include one oxide ( $n=1.5$ ) defect modeled by a cube of 20nm. The size of the defects is well below the source wavelength of 266nm. This structure is essentially the same as the one considered in the publication referenced.



First, we consider a bright field setup where we illuminate and collect light within a numerical aperture of 0.9 ( $NA_{in}=0.9$ ). Note that in the background we can identify a periodic signal associated with the  $m=\pm 1$  grating order of the periodicity of the SRAM structure along the y-direction. We see this behavior along the y-direction only because the period  $l_x$  for the x-direction is smaller than the period  $l_y$  for the y-direction so only the  $n=0$  grating order of the SRAM structure along the x-direction is allowed.

In the dark-field setup, we illuminate light within a numerical aperture of 0.7 ( $NA_{in} = 0.7$ ) and collect light between the numerical aperture of 0.7 and 0.9, the background signal can be removed to identify the defects more clearly.

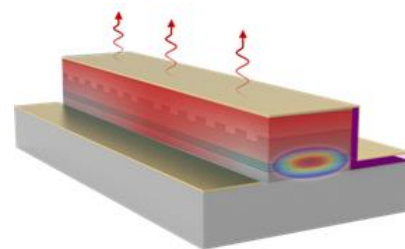




## Self-heating in AlGaInAs-InP multi-quantum well (MQW) laser

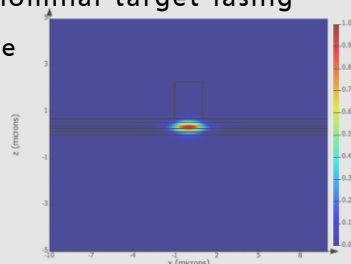
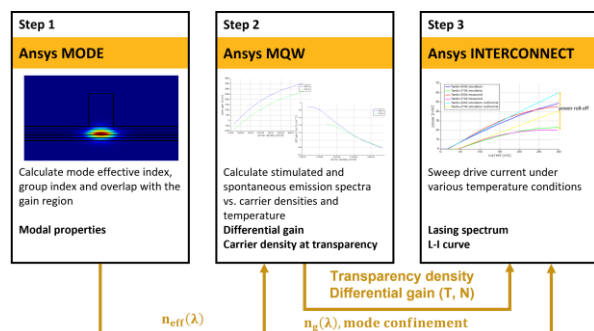
### Introduction

This example simulates an AlGaInAs-InP Fabry-Perot multi-quantum well laser diode including the self-heating effects. Calculated L-I curves with power roll-off as a result of self-heating at different ambient temperatures will be compared to the results reported in the literature.



### Results

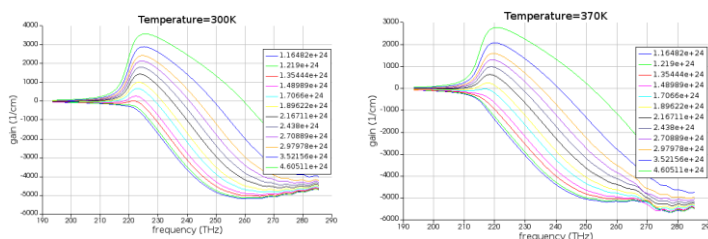
**Step 1:** The first step is to calculate the optical mode profile and extract the effective index and group index of the fundamental (TE) mode as well as its confinement factor with respect to the gain medium. These are all calculated in the vicinity of the nominal target lasing frequency and are expected to be locally weakly frequency-dependent. This calculation is done using the FDE solver.



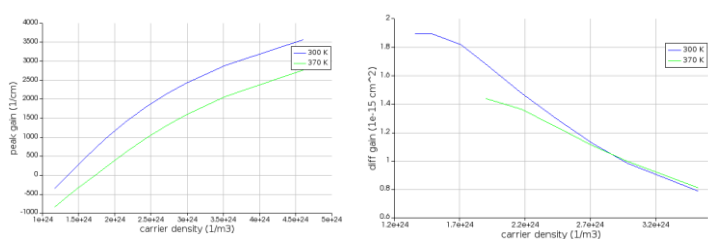
**Step 2:** using the MQW Gain Solver, a  $4 \times 4$   $k \cdot p$  calculation of the electronic bandstructure in the MQW gain medium is performed and the electronic bandgap, stimulated, and spontaneous emission spectra are extracted as a function of carrier density and temperature. MQW is a part of the multiphysics package (along with CHARGE, FEEM, and other products) and can be run within FE IDE environment with a graphical user interface. MQW can also be used through script commands in which case it can be run from any Ansys Lumerical product. In this case, it can be run either in FDE/FEEM (needed in the previous step) or INTERCONNECT (needed for the following step). The MQW GUI is included in this example. For the MQW script commands method please check one of our other examples.

In this example, due to high barrier thickness QWs can be considered uncoupled. In this case, calculations can be performed for a single QW to reduce simulation time. At the end of calculations, the results are scaled to represent the full number of QWs. The electric field is set to zero, which is a good approximation for the forward bias laser diode near and above the threshold.

From the calculated gain as a function of carrier density and temperature, we find the threshold density and differential gain and represent them as a first-order polynomial in temperature. This information will be used in the TWLM model in the next step.

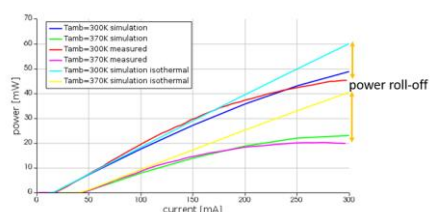


Stimulated emission (gain) for different temperature

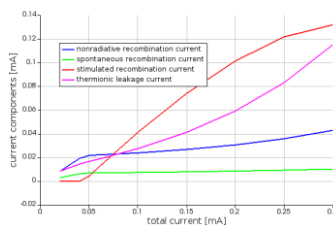


Peak gain and differential gain as a function of carrier density for different temperatures

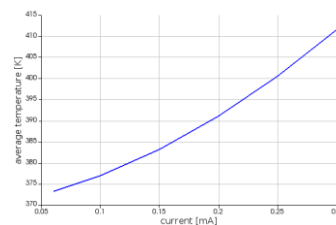
**Step 3:** using the TWLM element running in INTERCONNECT a time-domain 1D laser simulation is performed using a sweep over different drive currents, at different temperatures. This will be done considering the self-heating effects and also for the isothermal case. The optical power emitted in steady-state may then be plotted as a function of drive current to generate the L-I curve for both cases and compared to the reference. Also, different current components, temperature vs current over the threshold and spatial temperature profile are plotted.



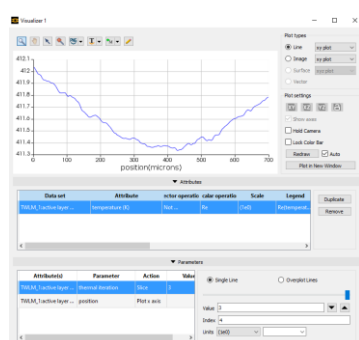
**L-I curves**



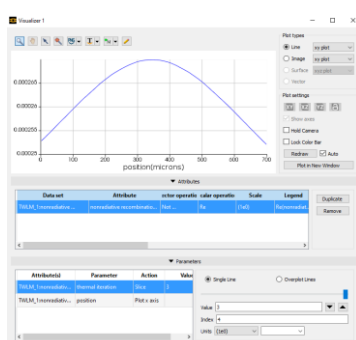
**Different components of current that add up to the total injection current**



**Active layer temperature profiles for each current**



**Spatial profiles of temperature and various heat sources**

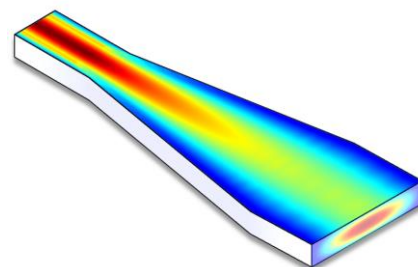
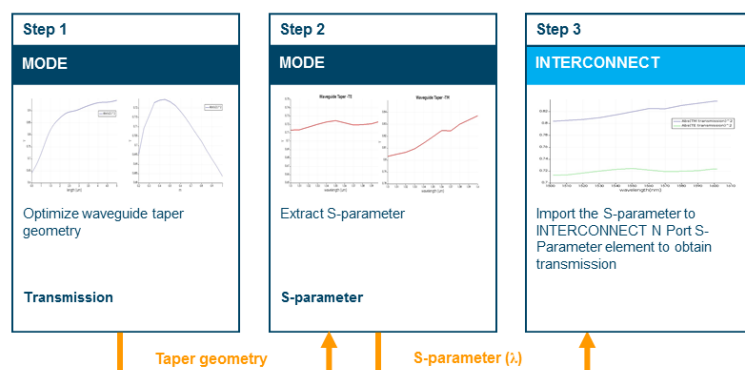


**Nonradiative recombination heat profile**

## Linear waveguide taper

### Introduction

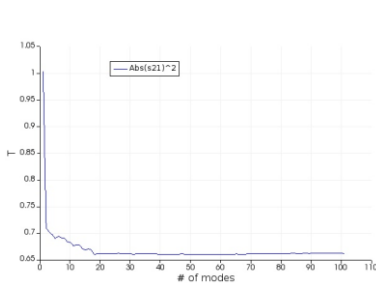
Calculate the optimal length and width of a linear waveguide taper to maximize the transmission. Use the device S-parameters to create a compact model of the waveguide taper in INTERCONNECT.



Efficient light coupling between two waveguides inside an optical circuit can be done with a waveguide taper. The coupling efficiency can be controlled via the taper length and shape. The EME solver is ideally suited to characterizing these devices. The device in this example is optimized for TE modes, but the approach can be extended to any design and polarization.

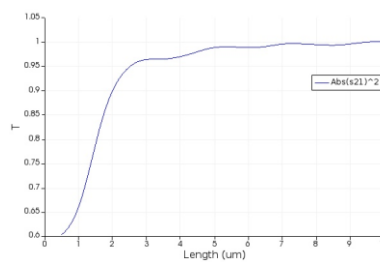
**Step 1:** Demonstrate how parameter sweeps can be used to optimize the taper. The example includes sweeps over the taper length and shape parameters. It could be easily extended to include other parameters. Transmission in the fundamental TE- or TM-mode is used as the figure of merit.

Mode convergence sweep



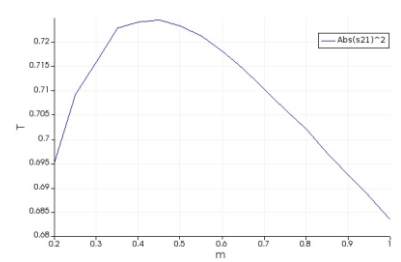
Transmission results from the output ports are converging with ~20 modes

Waveguide taper length sweep



Transmission as a function waveguide taper length sweep

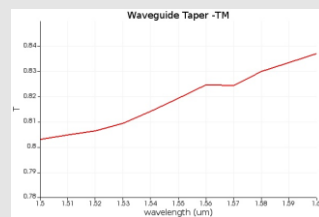
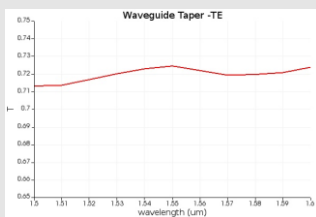
Waveguide taper shape sweep



Transmission through the output ports

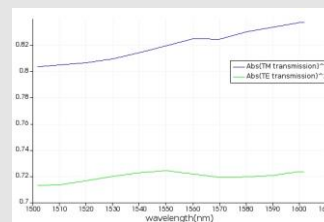
**Step 2:** Once an optimal taper shape is found, extract the S-parameters as a function of wavelength for each mode of interest. These will be used to create a compact model in INTERCONNECT.

S-parameter Extraction



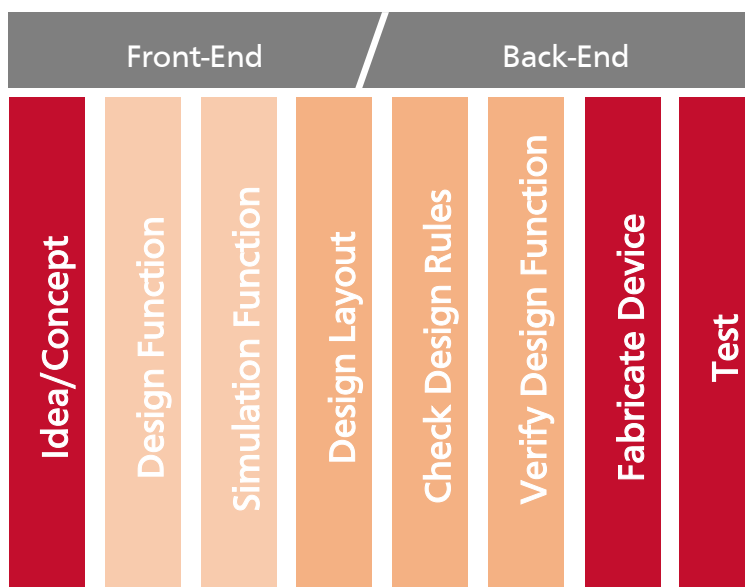
Transmission in the output ports for both TE- and TM-modes

**Step 3:** Create a compact model in INTERCONNECT, using the optical n port s-parameter (SPAR) element and import the data from step 2.



Transmission for both polarizations

## Design Workflow



### Key Benefits:

- Ansys Lumerical design tool suits front-end to back-end photonic design workflow. It makes ideas and concepts into reality.
- Ansys partners with leading foundries to prototype new design flows for lead customers, enhance manufacturing processes for photonics, and enable designers with photonic process design kits (PDKs) calibrated to foundry manufacturing processes.
- Ansys works with leading technology partners to develop powerful workflows.

## About CYBERNET

CYBERNET SYSTEMS MALAYSIA SDN.BHD. supports customers in Malaysia, Singapore, Thailand, Vietnam, and other ASEAN countries. They provide a wide variety of software, technical support, engineering services and training for Computer-Aided Engineering (CAE), Vehicle Simulation, Casting Simulation, Tolerance Analysis, and Digital Engineering solutions that combine CAE with emerging technologies for Digital Transformation, such as IoT, AR-VR, Digital Twin, Big Data analysis, and AI. More details on <http://www.cybernet.asia/>

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# CYBERNET

SYSTEM Suite for Photonic Integrated Circuit Simulation	HPC & Cloud	Interoperability Products
<b>INTERCONNECT</b> Photonic Integrated Circuit Simulation <b>CML Compiler</b> Photonic Model Development Kit <b>CML Publisher+</b> CML License Protection Option <b>Laser Library</b> Advanced Laser Modeling Extension <b>System Library</b> Advanced System Modeling Extension <b>Photonic Verilog-A Platform</b>	<b>FDTD</b> FDTD Accelerator FDTD Burst Pack  <b>MODE</b> MODE Accelerator	<b>Automation API</b> Python Lumerical Script  <b>Tool Integrations</b> IPKISS Interoperability KLayout Interoperability Matlab Interoperability Tanner Interoperability Virtuoso ADE Interoperability Zemax Interoperability  <b>Foundry Support</b> AIM Photonics Si-Ph Reader AMF Reader CompoundTek Reader HHI Reader imec Reader SMART Reader TowerJazz Reader
DEVICE Suite for Photonic Multiphysics Simulation		
<b>FDTD</b> 3D Electromagnetic Simulator <b>MODE</b> Waveguide Simulator <b>CHARGE</b> 3D Charge Transport Simulator <b>HEAT</b> 3D Heat Transport Simulator <b>DGTD</b> 3D Electromagnetic Simulator <b>FEEM</b> Waveguide Simulator <b>MQW</b> Quantum Well Gain Simulator <b>STACK</b> Optical Multilayer Simulator		

CYBERNET distributes and supports the full range of Ansys Photonic Component & Circuit Design Software.

## Other Services

CYBERNET has over three decades of experience in CAE business in Japan, China, Taiwan, and in the ASEAN region with well-experienced and highly-skilled engineers to support their customers.

- Engineering Services
- CAD creation
- CAE environment construction
- Sample model creation
- Customized technical training
- CAE launch support
- Consulting
- Optical measurement services

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