# Photonics Simulation Workflow in VSim

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# Overview

- Photonics
- Setup based
  - Geometries (CSG, GDS2)
  - Materials
  - Sources
  - Run parameters
  - Monitors
- Calculate modes
- Run

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- Visualization
- S parameters calculation



# Photonics devices

- Photonics: creating, manipulating and detecting light
- Si Photonics several dielectric materials as optical media:
  - Silicon: devices can be made using existing semiconductor fabrication techniques, and because silicon is already used as the substrate for most integrated circuits, it is possible to create hybrid devices in which the optical and electronic components are integrated onto a single microchip
  - Other materials: Si3N4

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- In VSim: EM with dielectric materials and vacuum wavelengths around 1.55 micron (telecommunication wavelength)
- Applications: 5G, HPC, telecommunications, data centers, LIDAR
  - Long distance low loss signal transmission
  - High density data (multiples wavelengths), with multiplexing-demultiplexing





## Structure of setup

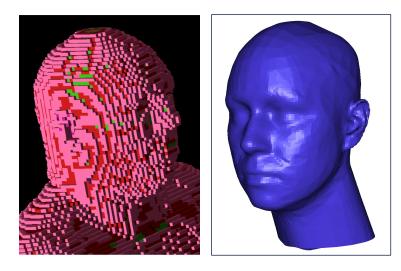
- Basic settings
- Geometry
- Materials
- Source
- Monitors (diagnostics)





## Basic settings to pay attention to

- Dimensionality
  - Typically 3
  - You can do 2 for very large systems, but need to make sure that the system is symmetric
- VSim calculates time step (DT) for users, but to see it, you need to go the run panel
- Dielectric solver
  - Permittivity averaging (more memory, more accurate)
  - Point permittivity (less memory, less accurate)
- Background permittivity (can be in vacuum or SiO2, for example)



Point

Averaged





# Geometry can be created manually or imported

- Manual creating: using primitives, arrays and boolean operations
- Import CAD:
  - STL, commonly used in digital printing
  - GDS2 file format typically used for specifying integrated circuits

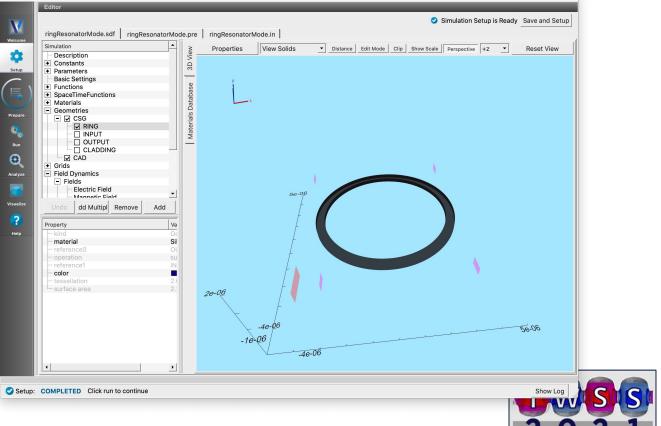




### Example of CSG geometry

Ring: subtraction of two cylinders Shapes used in Boolean operations do not have materials and can be hidden from the tree and the visualization

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# GDS2 import and editing

- GDS2 is 2D. There are specialized GDS2 tools: Klayout, gdspy, LayoutEditor
  - It is useful to play with your GDS2 file using these tools
  - GSD2 file consists of layers and does not contain information on z location and z size of the layer
- In VSim one can:
  - Import GDS2 file
  - Extract layers
  - Edit layers z information (thickness and location)
  - Perform Boolean operations on layers



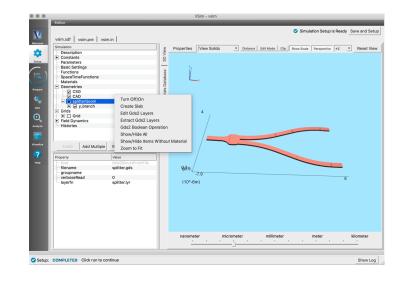


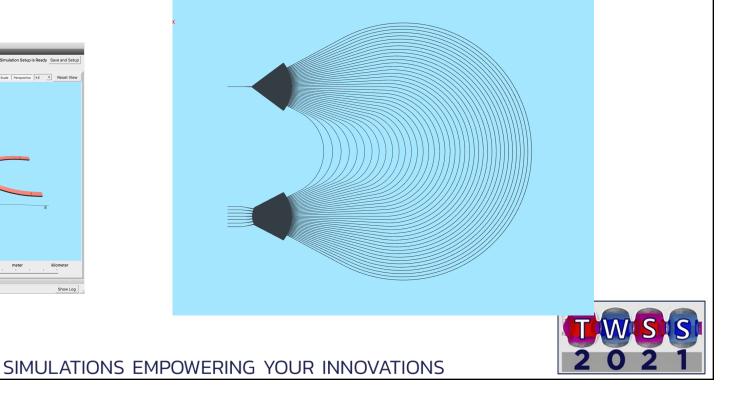
## Example of GDS2 geometry

Arrayed Waveguide Grating: mixed signal comes in and gets s separate frequencies at the output

#### Y-splitter

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	Bo	olean opera	tions on layers	
		GDS2 Boolean Operations		
Operation: A int	tersect B 💌			
Equality Toleranc	ce (m) 0			
Input A				
Gds2 object: e Choose layers:	exampleGeom	<u> </u>		
Include?	Index	Name		
~	255	substrate		
~	1	1/0		
~	2	pwell		
v	3	nwell		
Input B				
Gds2 Object:	exampleGeom	▼		
Choose layers:	Index	New		<b>•</b> • • •
Include?	Index 255	Name		Original
~	1	1/0		-
~	2	pwell		
-	3	nwell		
		Cancel Perform 0	ration	Union of all layers

One can create intersections, subtractions, unions of layers in 2D and assign them different z paramaters





#### Switch between viz and database: **Materials** Microring Resonator with Mode La Simulation Has Changed. Save and Setulation Background permittivity is set in Basic settings V \*ringResonatorMode.sdf ringResonatorMode.pre ringResonatorMode.in Simulation Materials Database File: DEFAULTS 🔻 Selected Material: Add To Simulation à Description Constants slative permittivit elaxation functio srmittivity functiontz os kind Name conductivity Setur Parameters Alumina dielectric 0.00135184 Q **Basic Settings** • Material database Functions Datubase Custom dielectric 0.` 1 fregBand SpaceTimeFunctions contains commonly used Si and SiO2 DebyeLorent... Debye-Lorentz 1.0 1.0 [alph pulse Prepare Materials pulsePrebuilt DrudeLorentz... Drude-Lorentz [alph Materials ¢, Silicon PEC conductor Silica Run Add to simulation Custom Sapphire dielectric 8.7e-10 9.9 Ð + Geometries Silica 2.03 + Grids dielectric 0 Edit shapes to choose material Analyz Silicon 0 12.11 dielectric Undo Add Multiple Remove Add Vacuum dielectric 0 1 Property Value Visualize absorbium particle ... • If you need another material: use ? conductivity 0.` dielectric 0.00135184 3.7 relative permittivity 3.5 bottle glass color 1 resistive ... dielectric 0.1 Custom material and set it properties A Setup: SIMULATION SETUP CHANGED Save the setup for simulation changes to take effect Show Log X Tech-X



# Light source are created by using functions or by using external fields

- Can be added as current or field
- Consists of the time function and space distribution
- Time dependency: use prebuilt functions
- Space function: use function (often we use Gaussian) or a use field profile from a 2D hdf5 file
  - External mode launcher using D field found by VSim
  - Mode propagating in x has invariant profile D(y,z)





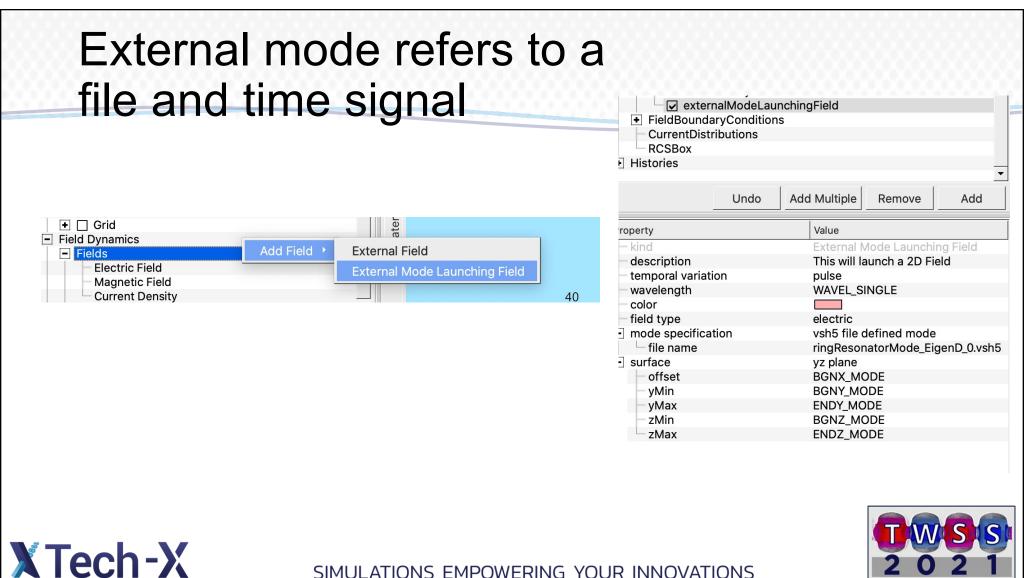
# One can use multiple prebuilt functions to construct time profile

Dasic Settings Functions Add SpaceTimeFunction chirp wave pulse - SpaceTimeFune pulse cosine flattop pulsePrebuilt cosine ramp Materials Geometries expression Grids feedback Field Dynamics qaussian - Fields **Electric Field** gaussian pulse Magnetic Field half sine pulse Current Density externalModeLaunchingField0 leaky channel FieldBoundaryConditions monochromatic excitation CurrentDistributions RCSBox plane wave pulse • product function python Value roperty radial cosine channel sinc hat function sine plane wave sum function User Defined

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For photonics we will use syncHat function: Uses min and max wavelengths and creates a flat signal limited by these values.





### Find modes using Prepare tab

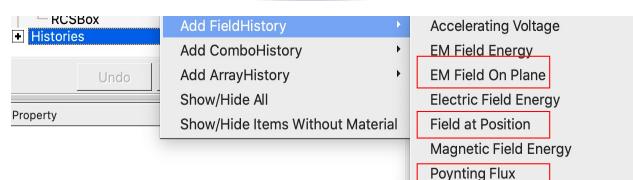
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Setup	Additional Analyzer Parameters	r r
(iii)	nModes 2	c t
$\bigcirc$	writeFieldProfile D	
Prepare		
×.		
Run		

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Runs simulation for 1 step, finds invEps, reads parameters of the external launcher and calculates modes. One can edit the name of the field file in the launcher upon inspecting modes in viz panel



# Diagnostics useful for photonics simulations



- History: a diagnostic collecting data at each time step
- EM Field on Plane: needed for S parameters calculation

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2e

Pseudo-potential

**Pseudo-potential at Coordinates** 

**Pseudo-potential at Indices** 

# Run panel

- Number of steps so that the signal goes several times across the syste to be able to get frequency domain data
- Dt is default (calculated by VSim)
- Look at the size of the dump file and plan the dumping periodicity accordingly (monitors/histories colle data at each step)

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	Parameters Run Mode	
-	Values entered here will override values from the simulation file.	
l ste	Time Step         Default Value (7.343490630124558e-17)         Value: 7.343490630124558e-17         Use Variable:	Parameters Run Mode
n		
	Number of Steps	Mode: Parallel
	Value:         63817         Default Value (60000)	
	Use Variable: NUMSTEPS	Physical Cores on Machine 6
nc	Dump Periodicity	Licensed Cores not found
	Value: 6000 Default Value (6000)	Number of Processes 6
lle	Use Variable:	
	Restart at Dump Number	Host File
	Value:	Other MPI Options
	Use Variable:	
	✓ Dump at Time Zero	
	No Particle Sorting	
	Disable Per-Rank Output	
	Custom Run Options	
	Reset to Setup Values	TWCC
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# Visualization

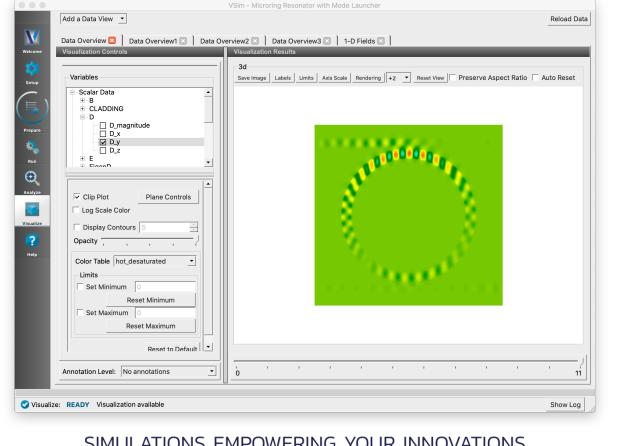
- Can add multiple windows: use different windows for different dimensions (1D fields, one data overview for 2D fields, another data overview for 3D fields)
- Cuts
- Isosurfaces
- Color schemes
- Individual controls of each plot





### See the field moving

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#### Look at materials

	- Microring Resonator with Mode Launcher	1			
Add a Data View 💌	Reload Data				
Data Overview 🗵 🛛 Data Overview1 🗵 📄 Data Overview	2 🗵 📔 Data Overview3 🗵 📔 1-D Fields 🗵 📄				
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externalModeLaunchingFieldField		Ori	ain		
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□ invEps □ □ invEps_magnitude			L		2.  0
			Plane2		
•		No			
Analyze Clip Plot Plane Controls		X:	0	Y: 1	Z: 0
Log Scale Color		Ori	gin		
Visualize Display Contours 5		X:	0	Y: 0	Z: 0
Opacity        /			Plane3		
Color Table hot_desaturated		No			
Limits		X:	0	Y: 0	Z: 1
Set Minimum 0		Ori	ain	,	1
Set Maximum 1.73205		X:	0	Y: 0	Z: 0
Reset Maximum			10	1.  0	2.  0
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	/				
Annotation Level: No annotations					
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Visualize: <b>READY</b> Visualization available	Show Log				
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	Look	at	mo	des
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Welcome	Data Overview Data Overview1 Data C Visualization Controls	Dverview2 🔀   Data Overview3 💌   1-D Fields 🗷
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₩.	<ul> <li>EigenD</li> <li>EigenD_magnitude</li> <li>EigenD_x</li> </ul>	
Run		
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Analyze	Clip Plot Plane Controls	
	Log Scale Color	
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Help		
	Color Table hot_desaturated  Limits	
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	e: <b>READY</b> Visualization available	Show Log



# Source in the input

	zation Controls	Visualization Results
Vari	ables	3d Save Image Labels Limits Axis Scale Rendering + z  Reset View Preserve Aspect Ratio Auto Reset
Prepare	externalAuxField externalModeLaunchingFieldField @externalModeLaunchingFieldField DexternalModeLaunchingFieldField OUPUT externalAuxField OUTPUT externalAuxField externalAuxFi	
Analyze	Clip Plot Plane Controls Log Scale Color Display Contours 5	
	Set Maximum 0 Reset Maximum Reset to Default Tation Level: No annotations	



### **Calculating S parameters**

 S parameter is ratio of the integrated power flux going though output and input as a function of vacuum wavelength

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•	VSim - Microring Resonator with Mode Launcher	
Analysis &Controls	Analysis & Results	
Search:	computeWaveguideModes.py 🔝 computeSParamsViaOverlapIntegral.py 🔀	
Available Analyzers: Open	Run Automatically After Engine.     Order:     1     Analyze     Stop     Clean	ear Output
addSpeciesWithKinEnrgInEV.py annotateSpeciesAbsPtcIData2.py annotateSpeciesAbsPtcIData2.py annotateSpeciesAbsPtcIData2.py computeSpanosPtcIData2.py computeSpanosPtcIData2.py computeSpanosPtcIData2.py computeBeam2ModeCoupling.py computeBeam2ModeCoupling.py computeBeam2ModeCoupling.py computeSem2ModeCoupling.py computeSem2ModeCoupling.py computeSem2ModeCoupling.py computeSem2ModeCoupling.py computeSem2ModeCoupling.py computeSem2ModeCoupling.py computeSem2ModeCoupling.py computeSem2ModeCoupling.py computeSem2ModeCoupling.py computeSem2ModeCoupling.py computeSem2ModeCoupling.py computeFieldRelintensityHilbert.py computeFieldRelintensityHilbert.py computePtcIBalance.py computePtcIBalance.py computeSparamsFix.py computeSparamsFix.py computeSparamsFix.py computeSparamsFix.py computeThrust.py computeTimeSeriesAmplitude.py computeTimeSeriesFrequency.py computeTimeSeriesFrequency.py computeTimeSeriesFrequency.py computeTimeSeriesFrequency.py computeTimeSeriesFrequency.py convertFieldComponentCatToCyI2.py convertFieldComponentCatToCyI2.py convertPtcIC	<pre>simulationName ringResonatorMode minWavelength 14e-06 Use Variable: WAVEL_MIN maxWavelength 17e-06 Use Variable: WAVEL_MAX inPlane slab0 firstStepinPlane Use Variable: vusr/local/opt/volatile-llvm_appleclang/vsim=r625-626ctk14727M-pycst/VSim=1 VsinComposer.app/Contents/Resources/engine/bin/ computeSParamsViaOverlapIntegral.pysimulationName="ringResonatorMode" maxWavelength=17e-06"</pre>	ength. 12.0/ -
		Show Loo



## Visualize S parameters

- Go to Viz panel
- Reload data

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• Add 1D visualization of available data

