lumerical
illuminating the way

FDTD *Solutions*

Workflow and GUI
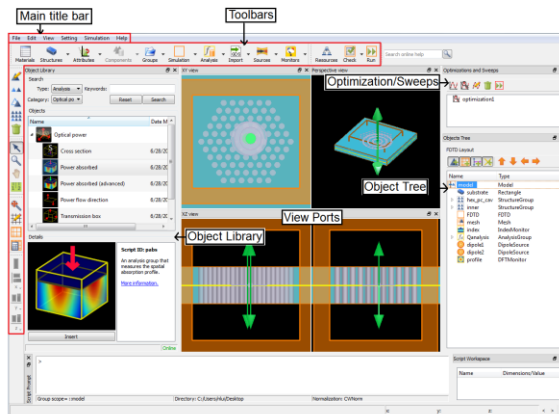
FDTD Solutions features

- Main window
- Working with simulation objects
- Object library
- Monitor types
- Running a simulation
- Optimization and parameter sweeps
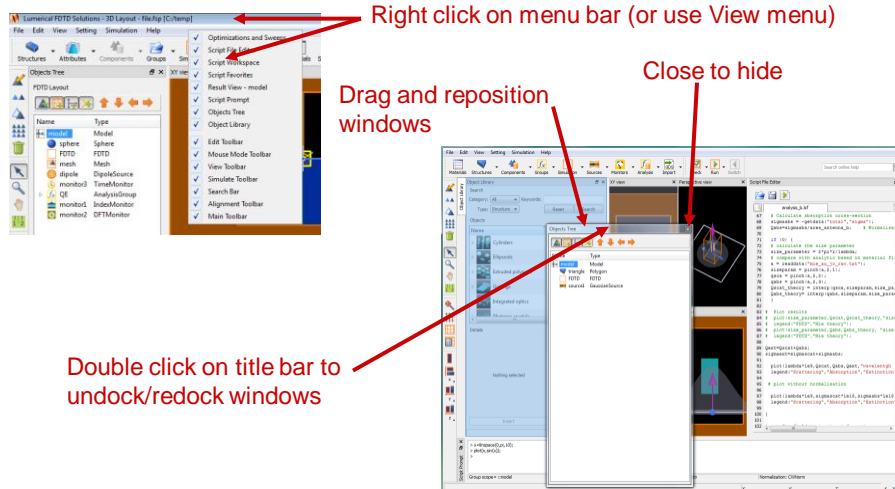- Analysis

Main window

The graphical CAD environment is required to setup and analyze all simulations. It is also required to run all scripts.

Online Help – Layout editor
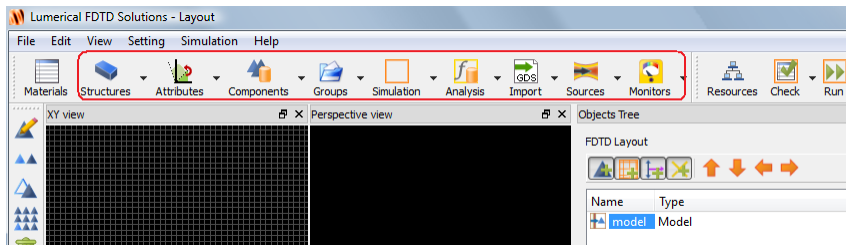http://docs.lumerical.com/en/fdtd/ref_layout_editor.html

Showing, hiding, moving windows

Right click on menu bar (or use View menu)

Close to hide

Drag and reposition windows

Double click on title bar to undock/redock windows
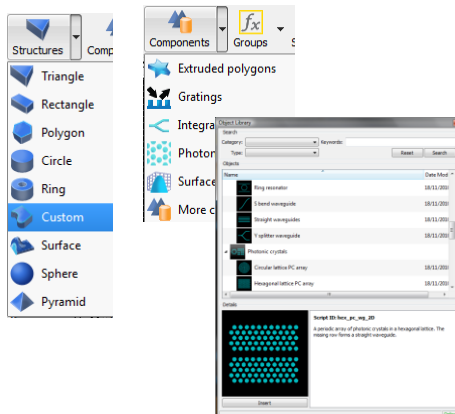
Simulation objects

Object types:
•Structures
•Simulation
•Sources
•Monitors

Online Help – Simulation resources
http://docs.lumerical.com/en/fdtd/ref_sim_obj.html

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Structures and structure groups

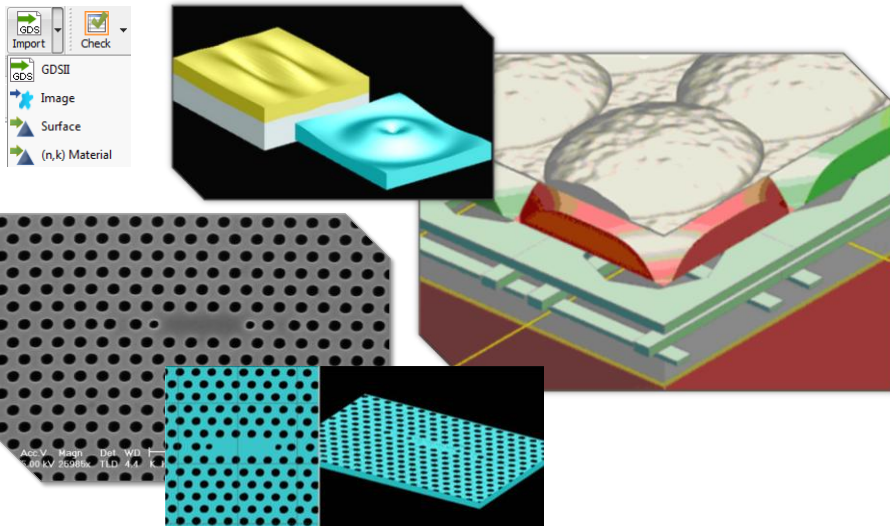Advanced objects can be obtained via the Object library
•Structure groups

Online Help – Object library
http://docs.lumerical.com/en/fdtd/ref_layout_editor_object_tree.html
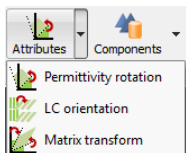
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Structures – import options

© 2012 Lumerical Solutions, Inc.
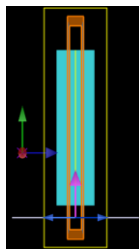
Structures - grid attributes

Permittivity rotation
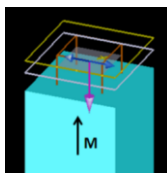• rotate the permittivity tensor

LC orientation
• specify arbitrary orientations for the liquid crystal director
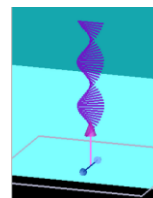
Matrix transform
• add an arbitrary unitary matrix to the dielectric tensor

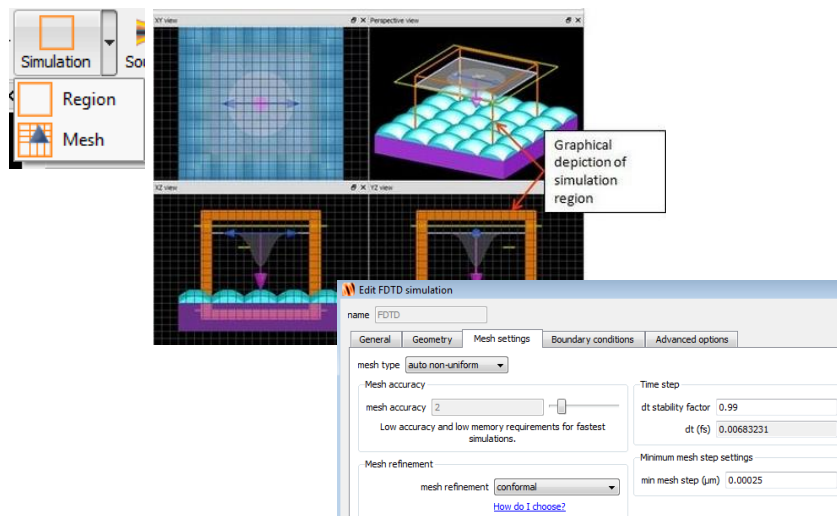Faraday Effect   Magneto-Optic Kerr Effect   LCD

Online Help – Object library
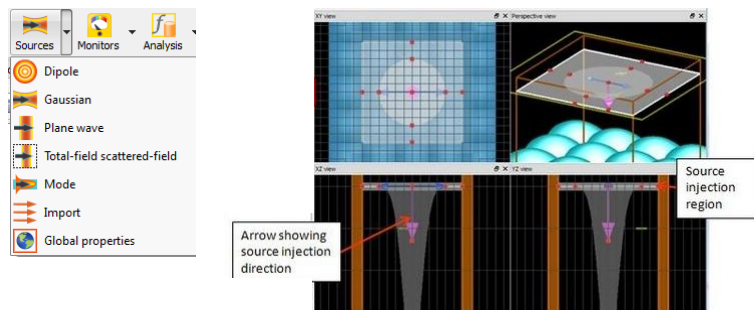http://docs.lumerical.com/en/fdtd/ref_sim_obj_attributes.html
http://docs.lumerical.com/en/fdtd/anisotropy.html

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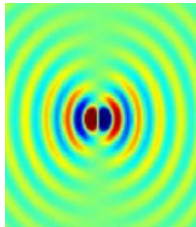# Simulation

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Sources

Online Help – Sources
http://docs.lumerical.com/en/fdtd/user_guide_source_movies.html
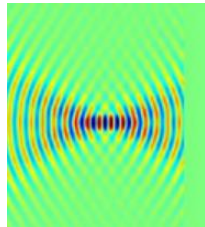http://docs.lumerical.com/en/fdtd/ref_sim_obj_radiation_sources.html
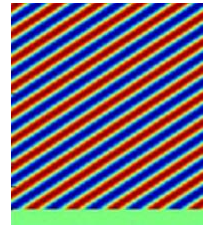
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Basic Sources

Dipole   Gaussian   Plane

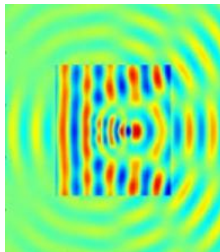For source movies, please visit
http://docs.lumerical.com/en/fdtd/user_guide_source_movies.html
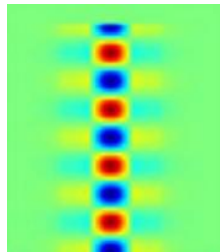
Advanced Sources
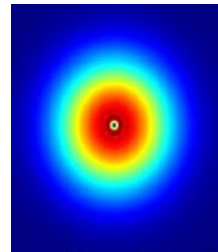
Mode   TFSF   User-defined

For source movies, please visit
http://docs.lumerical.com/en/fdtd/user_guide_source_movies.html

Monitors and analysis groups
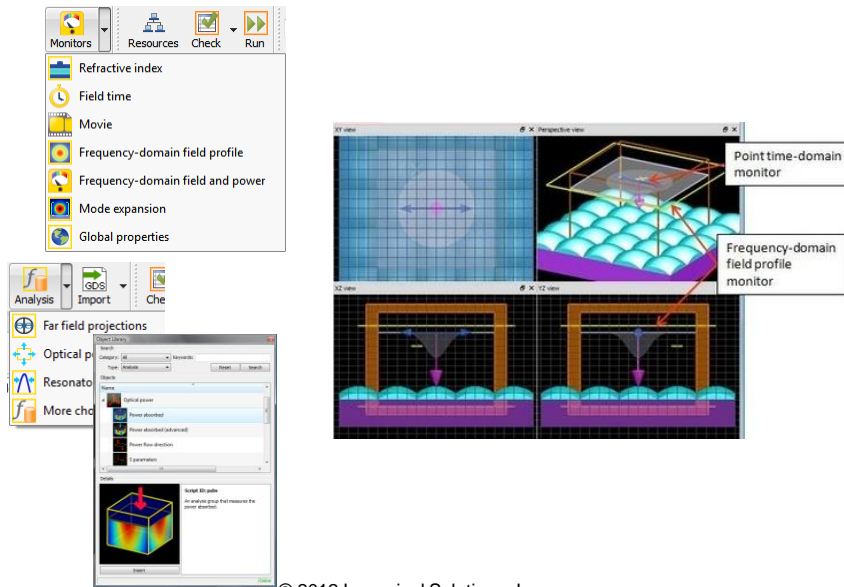
© 2012 Lumerical Solutions, Inc.

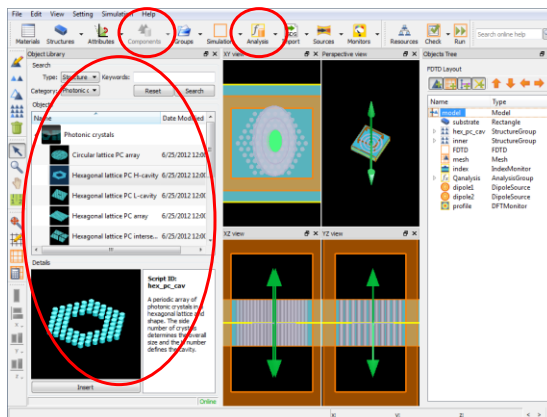## Object library

Advanced objects can be obtained via the Object library
•Structure groups
•Analysis groups

Online Help – Object library
http://docs.lumerical.com/en/fdtd/ref_layout_editor_object_library.html

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Monitors

FDTD Solutions has several monitors

- **Index** monitors to record material properties
- **Movie** monitors to create mpg movie files
- **Time** monitors to record electromagnetic fields as a function of time
- **Frequency** monitors to perform fourier transforms during the simulation
- **Mode expansion** monitors expand field profiles into a basis set of supported waveguide modes

Index monitors

Index Monitors record material properties
Use it to make sure you are simulating the right structure!
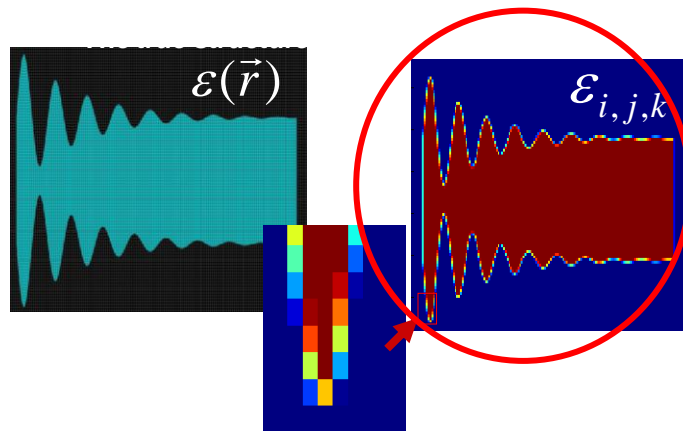
Movie monitors

Use Movie Monitors for
- visual aids in presentations!
- observe dynamic light interaction with the structure
- to develop intuition for what the simulation is doing
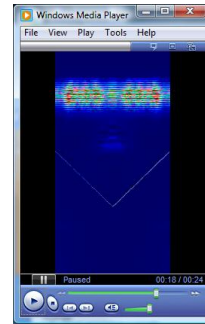- to make sure the simulation is doing qualitatively what you want

Time monitors

Time Monitors record E(t) and H(t)
- We use time monitors to
  - : Ensure the simulation has run long enough
  - : Look for resonant frequencies by doing a fast Fourier transforms (fft) of a time signal
    - Find modes of resonant cavities
    - Bandstructure calculations
- Normally data is recorded at single points
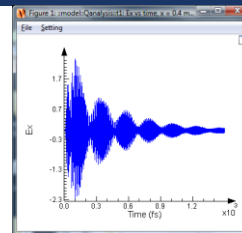
E(t) from a cavity simulation
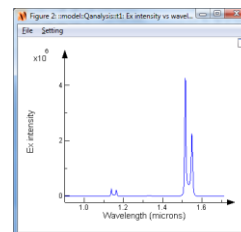
fft of above data

Online Help – PC cavity getting started example
http://docs.lumerical.com/en/fdtd/pc_micro_cavity_tutorial.html

Frequency monitors

Frequency Monitors provide frequency domain (i.e. steady state or CW) data

- : Fully vectorial CW data obtained via fourier transform of time domain fields.
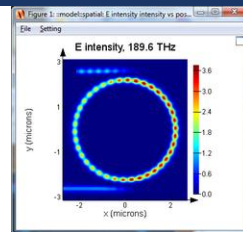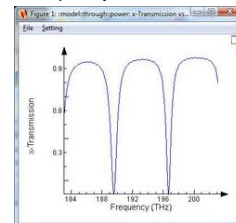- : Obtain data at many wavelengths from a single simulation! Wavelength range must be specified in advance
- : Allow us to calculate:
  - transmission, reflection, absorption, scattering, spatial field profiles, far field projections, local (near) field enhancements, light extraction enhancement

|E|^2 at one frequency

Power transmission(f)

Online Help – Ring resonator getting started example
http://docs.lumerical.com/en/fdtd/pc_micro_cavity_tutorial.html
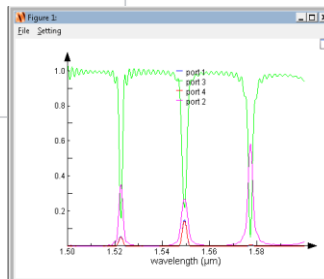

Mode expansion monitors
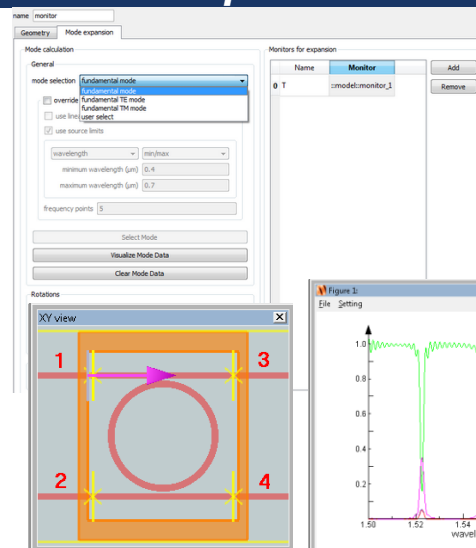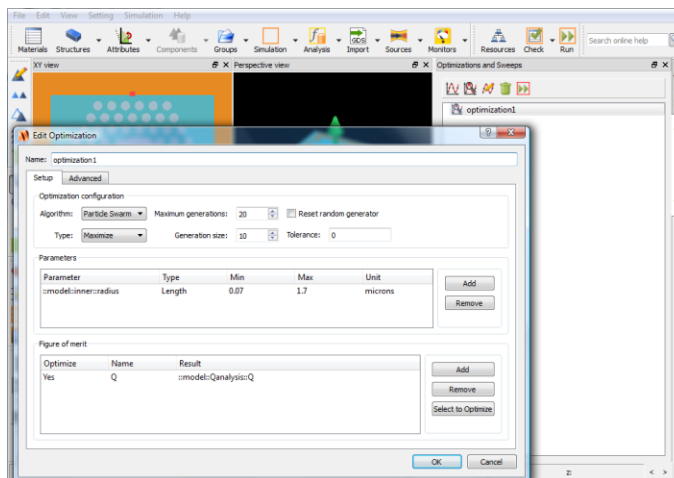

Mode expansion monitors expand an arbitrary field profile from a Frequency monitor using waveguide modes as a basis for the expansion

- Power coupling into waveguide modes
- S-parameter extraction to characterize components for further simulation with INTERCONNECT

Optimization and parameter sweeps

Online Help – Optimization and sweeps
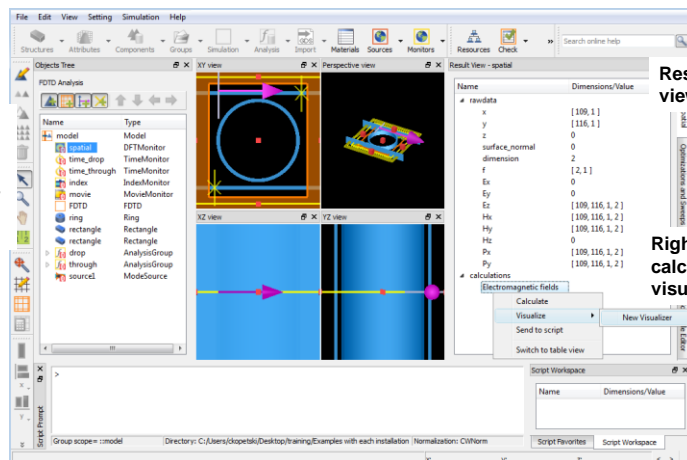http://docs.lumerical.com/en/fdtd/user_guide_run_optimization.html
http://docs.lumerical.com/en/fdtd/user_guide_run_parameter_sweep.html

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Analysis of results

Browse Object tree.
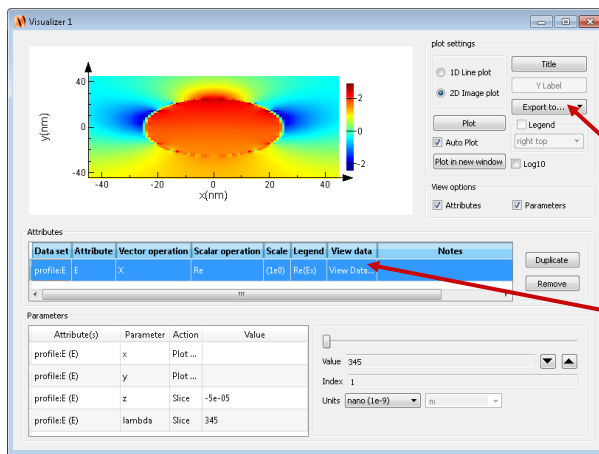
Red icon means the object has simulation data

Results viewer

Right click to calculate and visualize results

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Basic analysis - Visualizer

Select data to display from Attributes and Parameters sections

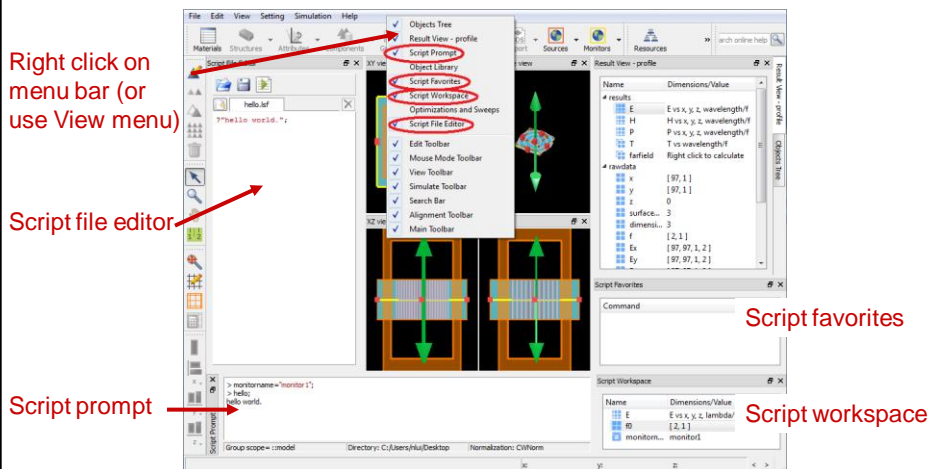Export data as jpeg, text file, or copy and paste into Excel

View data in tabular format and select all or portion of data to export

Online Help – Visualizer
http://docs.lumerical.com/en/next_fdtd/ref_analysis_visualizer.html

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Advanced analysis with scripting

Right click on menu bar (or use View menu)

Script file editor

Script prompt

Script favorites

Script workspace

Online Help – Scripting resources
http://docs.lumerical.com/en/fdtd/ref_scripts_scripting_language.html
http://docs.lumerical.com/en/fdtd/user_guide_scripts.html

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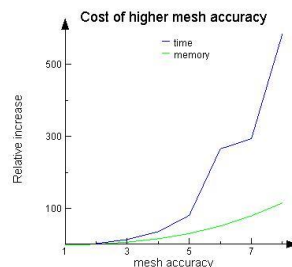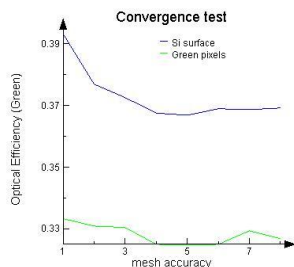
FDTD Solutions Workflow Example

1. Create Physical Structures
2. Set Simulation Parameters
3. Define Sources
4. Define Monitors
5. Run Simulation
6. Analyze Results
7. Repeat if necessary

We will go through these steps in the following example.

Convergence testing

- Use a coarse mesh for initial simulations
  : Memory scales as $1/dx^3$
  : Simulation time scales as $1/dx^4$

Online Help – Testing convergence
http://docs.lumerical.com/en/fdtd/user_guide_testing_convergence.html
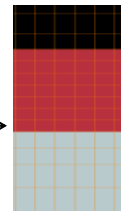
Simple example

Part 1: Measure the transmission through a 50 nm thick slab of Si on glass from 400 to 800nm

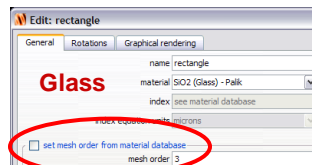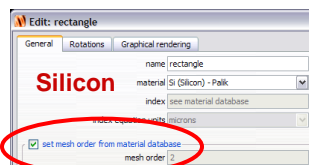| 1. Physical Structures - Set drawing grid to 25nm - Create structures	2. Simulation Area - Set dimension to 2D - BC (Periodic in x, PML in y) - "x span"=400nm, "y span"=1 micron - Mesh accuracy of 2

3. Sources
- Plane wave source, from glass side to air
- Wavelength 400 to 800nm
	4. Monitors
	- Movie monitor
	- Index monitor over entire structure
	- Time monitor in Si layer
	- Transmission/Reflection monitors "R", "T"
	  (100 frequency points each)
	- Full profile over entire structure
	  (5 frequency points)

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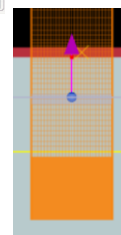

Simple example

- Recalculate and look at the FDTD mesh
  - : Do we need a mesh override region?
- What happens at the interface?
  - : Which material is used here?
- For precise control set mesh order correctly

The interface point will be Silicon!

Silicon

Edit: rectangle
General | Rotations | Graphical rendering
name rectangle
material Si (Silicon) - Palik
index see material database
☑ set mesh order from material database
mesh order 2

Glass

Edit: rectangle
General | Rotations | Graphical rendering
name rectangle
material SiO2 (Glass) - Palik
index see material database
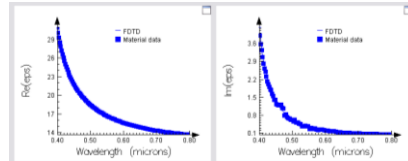☐ set mesh order from material database
mesh order 3

- Be careful to extend structure into the PML boundary condition

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Simple example

- Check memory requirements!
- Check material fits

- Save simulation file under name **simple_example.fsp**
- Run simulation
  - : Note when the simulation "auto-shutoff" occurs
    - Can we reduce the maximum simulation time for the next simulation?
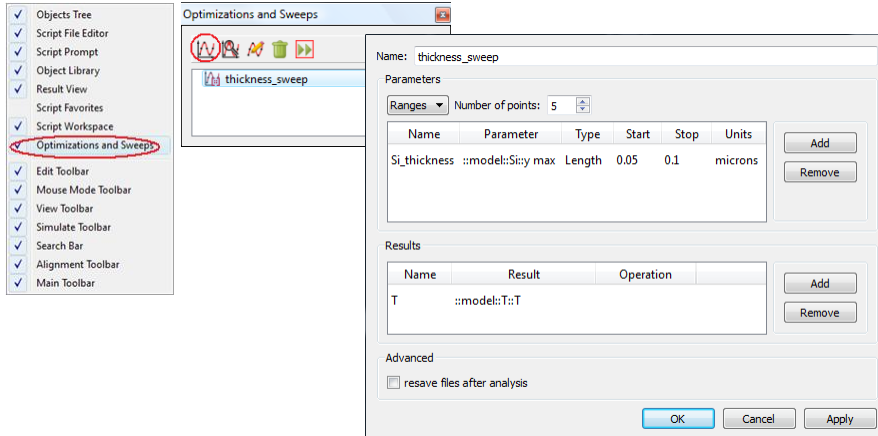

Simple example

- Analyze results
  - : Run the movie: movie.mpg
  - : Visualize monitor results by right-clicking object in Objects Tree or selecting the object and right-clicking the result in Results View window
  - : Plot Ez vs time (auto-shutoff?)
  - : Image n and k. Is the structure correct?
  - : Plot transmission vs wavelength
 - : Image $|E_z|^2$ at 3 different wavelengths
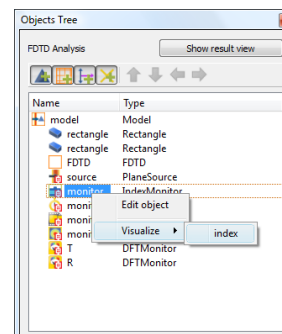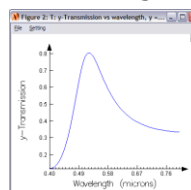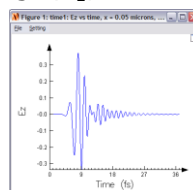
Simple example

Part 2: Set up a parameter sweep to sweep the thickness of the Si layer from 50 nm to 100 nm over 5 points.

Simple example

- Visualize sweep results
  - : Change the plot type to 1D Line plot to get transmission spectrum at a certain thickness
  - : Select the Si_thickness parameter and move the slider to plot the transmission spectrum at each thicknesses
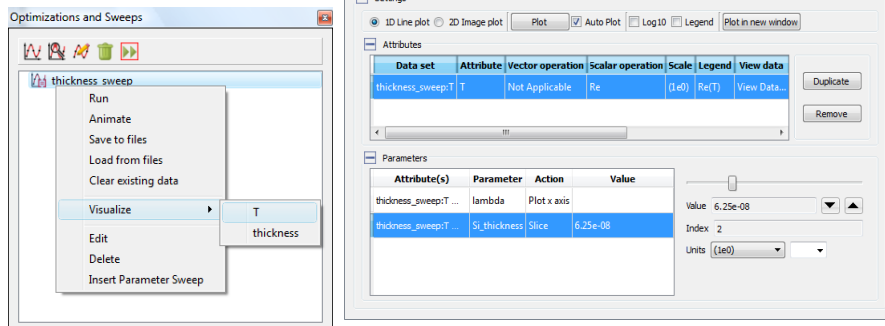
Where to find help and examples

- **Online help** at www.lumerical.com/fdtd_online_help
  - : New features summary
  - : Installation manual
  - : Getting started
  - : Reference guide
  - : Script function reference
  - : User guide
  - : Application help
- Application summaries
  - : www.lumerical.com/fdtd_applications

Getting help

- Technical Support
  - : **Email**: support@lumerical.com
  - : **Online help**: www.lumerical.com/fdtd_online_help
    - Many examples, user guide, full text search, getting started, reference guide, installation manuals
  - : Phone: +1-604-733-9006 and press 2 for support
- Sales information: sales@lumerical.com
- Find an authorized sales representative for your region:
  - : www.lumerical.com and select **Contact Us**