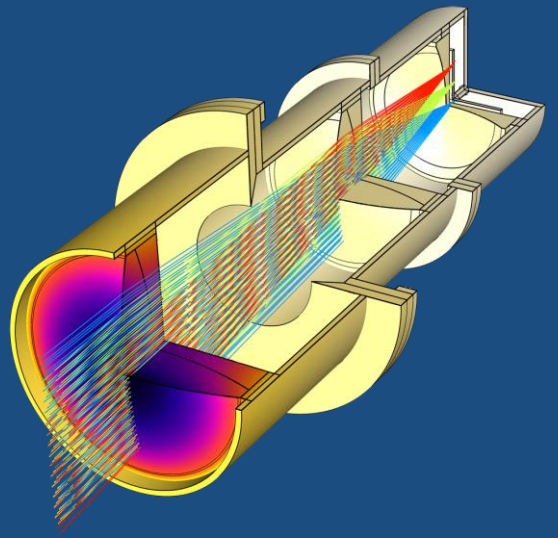


Image Simulation and the Path from Ray Optics to Wave Optics and Real Physical Devices Modeling

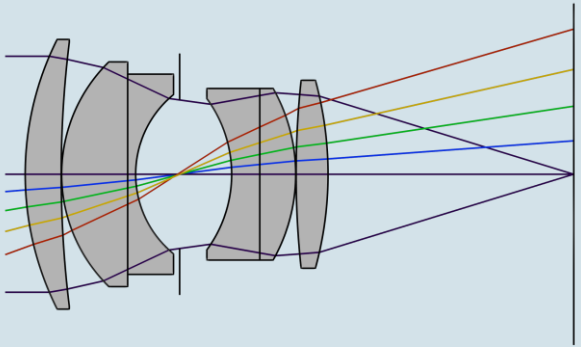
Cesare Tozzo, Dr.
COMSOL

Agenda

- Image Simulation allows to simulate the appearance produced by optical lens systems
- Image Simulation will be shown on a double Gauss lens system
- Multiphysics: the theoretical device behavior will be integrated with structural-thermal-optical performance (STOP) analyses
- Quantify thermal drift performance of the physical system under real thermal and mechanical usage conditions
- Extension of same multiphysics concept for wave optics, light-matter interaction, plasmonic resonances, semiconductor devices modeling

Image simulation from a double Gauss lens

- Geometrical Optics
  - Available with Ray Optics Module of COMSOL Multiphysics®
  - Ray tracing in homogeneous and graded media
  - Detailed analysis of ray intensity and polarization
  - Variety of features for releasing rays and controlling interaction with boundaries
  - Multiphysics couplings to model thermal effects
  - Tools for multiscale electromagnetics modeling



Double Gauss Lens

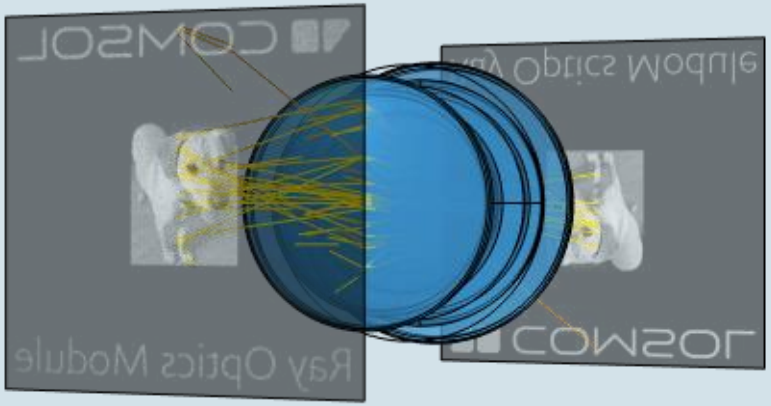
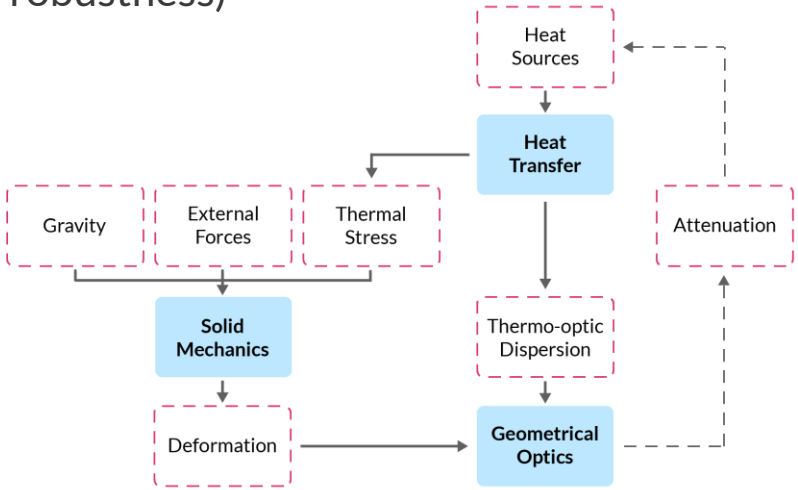
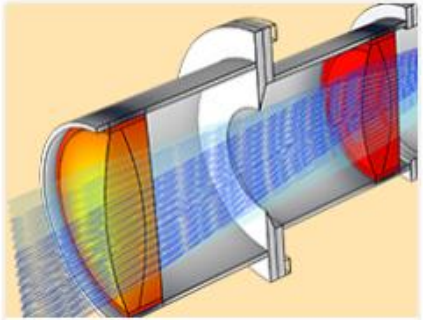


Image Simulation (picture on the left is projected on the right)

Structural-Thermal-Optical Performance (STOP) Analysis

- Procedure to accurately model optical systems under extreme conditions (laser focusing systems, solar concentrator / receiver systems…)
- Diverse application areas with several common features (wide range of temperatures, possibility for thermal stresses, need for high accuracy / robustness)





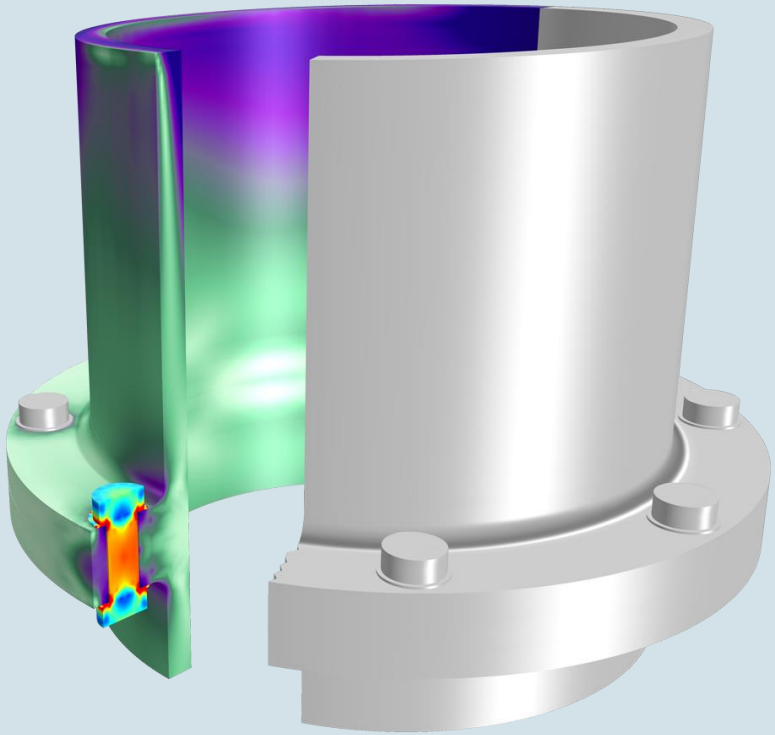
How to Perform a STOP Analysis with COMSOL Multiphysics®

November 5, 2018

Interested in structural-thermal-optical performance (STOP) analysis? We go over the theory, background, and how to perform such an analysis in the Ray Optics Module.

Structural Mechanics

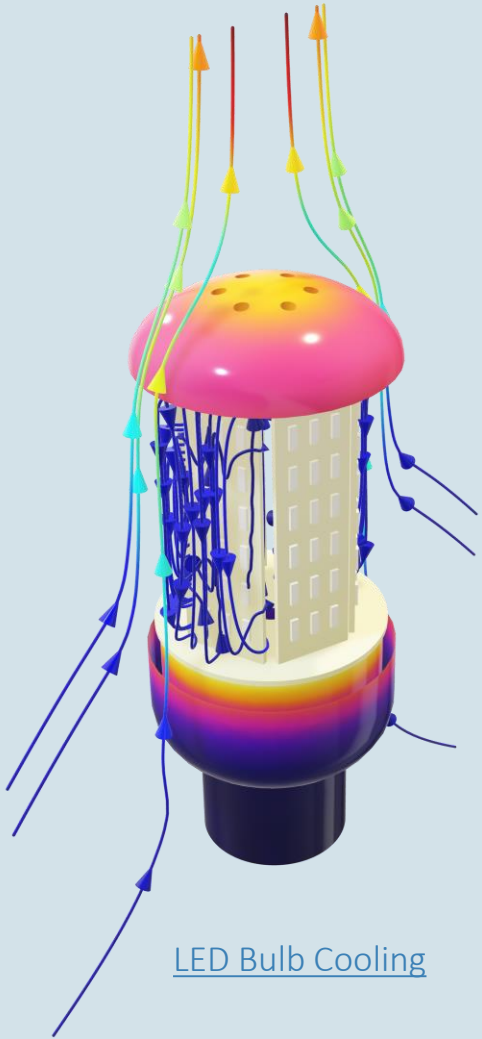
- Compute stresses and strains
- Variety of constraints and forces
- Shells, plates, membranes, beams, and trusses
- Extend the modeling capability with specialized add-on modules:
  - Multibody Dynamics Module
  - Fatigue Module
  - Nonlinear Structural Materials Module



Prestressed bolt

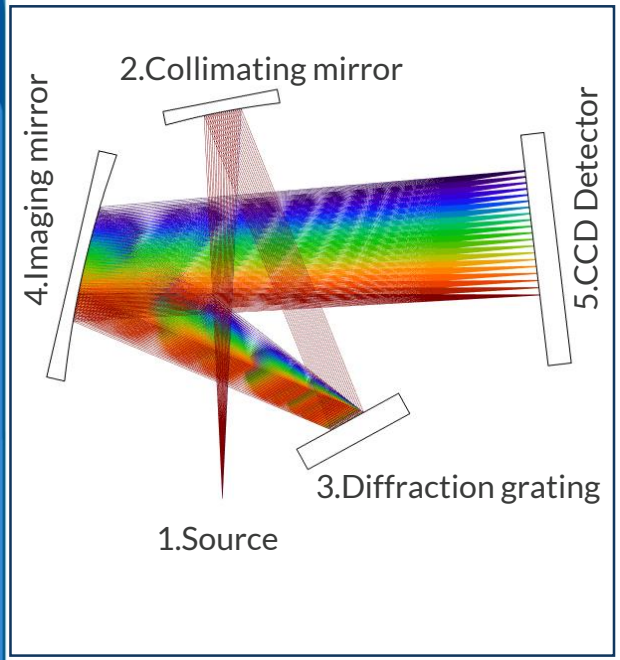
Heat Transfer

- Conduction, Convection, Radiation
- Nonisothermal flow
- Forced and natural convection
- Surface to surface radiation
- Radiative transfer through participating media
- Electromagnetic heating
- Thin layers and shells
- Phase change

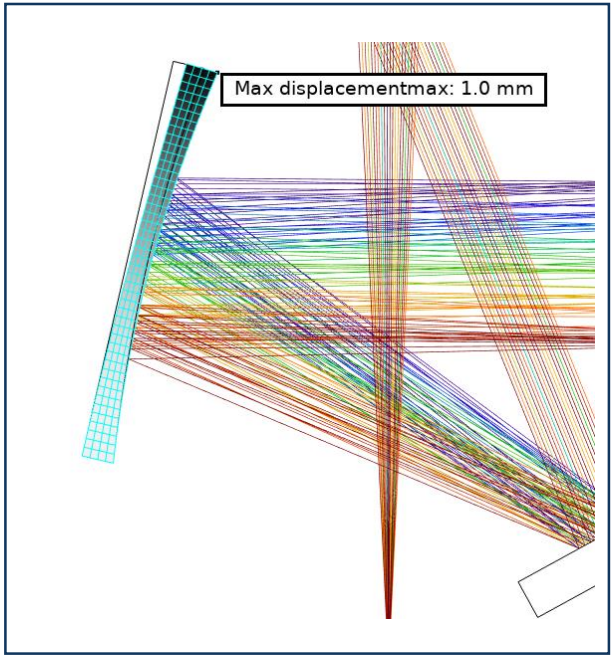


LED Bulb Cooling

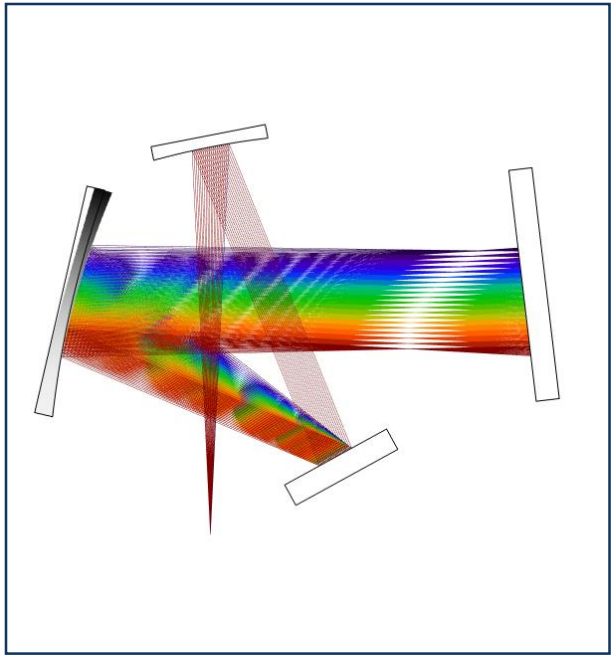
Ray Optics is fully compatible with Moving Mesh



Czerny-Turner monochromator (undeformed ray tracing result)

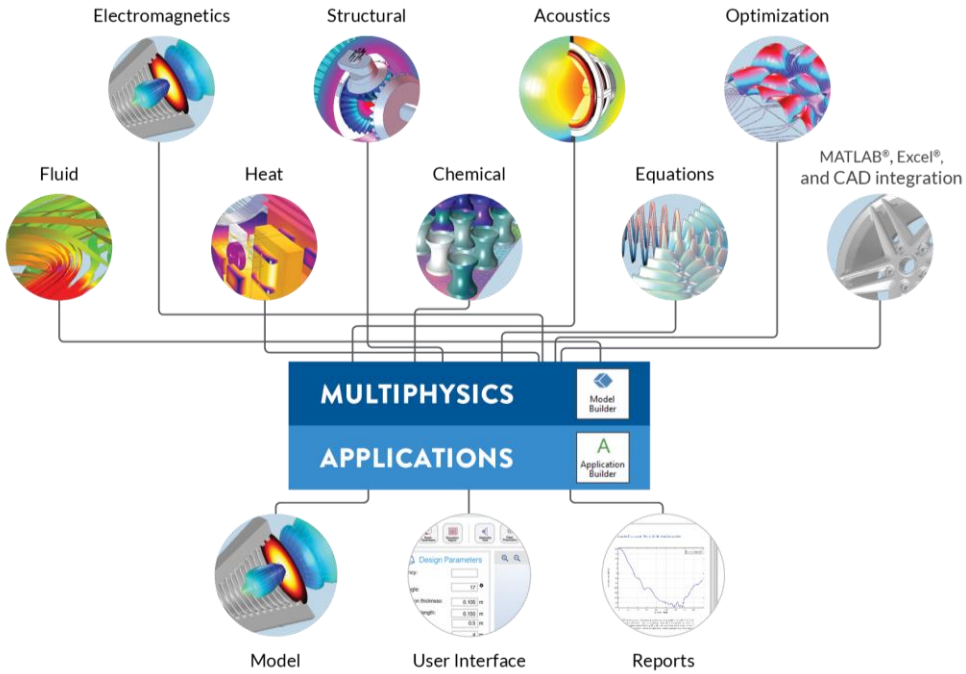


2[kg] bending load on the spherical imaging mirror (4)



Ray tracing occurs on top of deformed configuration

COMSOL Multiphysics®



The COMSOL® Software Product Suite

Platform Product

COMSOL MULTIPHYSICS®

DEPLOYMENT PRODUCTS

- COMSOL Compiler™
- COMSOL Server™

Distribute simulation applications created with COMSOL Multiphysics.

Structural

Thermal

Optical

ADD-ON PRODUCTS

ELECTROMAGNETICS

- AC/DC Module
- RF Module
- Wave Optics Module
- Ray Optics Module
- Plasma Module
- Semiconductor Module

FLUID & HEAT

- CFD Module
  - Mixer Module
- Microfluidics Module
- Porous Media Flow Module
- Subsurface Flow Module
- Pipe Flow Module
- Molecular Flow Module
- Metal Processing Module
- Heat Transfer Module

STRUCTURAL & ACOUSTICS

- Structural Mechanics Module
  - Nonlinear Structural Materials Module
  - Composite Materials Module
  - Geomechanics Module
  - Fatigue Module
  - Rotordynamics Module
- Multibody Dynamics Module
- MEMS Module
- Acoustics Module

CHEMICAL

- Chemical Reaction Engineering Module
- Batteries & Fuel Cells Module
- Electrodeposition Module
- Corrosion Module
- Electrochemistry Module

MULTIPURPOSE

- Optimization Module
- Material Library
- Particle Tracing Module

INTERFACING

- LiveLink™ *for* MATLAB®
- LiveLink™ *for* Excel®
- CAD Import Module
- Design Module
- ECAD Import Module
- LiveLink™ *for* SOLIDWORKS®
- LiveLink™ *for* Inventor®
- LiveLink™ *for* AutoCAD®
- LiveLink™ *for* Revit®
- LiveLink™ *for* PTC® Creo® Parametric™
- LiveLink™ *for* PTC® Pro/ENGINEER®
- LiveLink™ *for* Solid Edge®
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STOP Analysis on the double Gauss lens device, result

Typical magnified deformation under thermal load (lens constrained from thermally expanding bottom clamping, included by means of boundary condition)

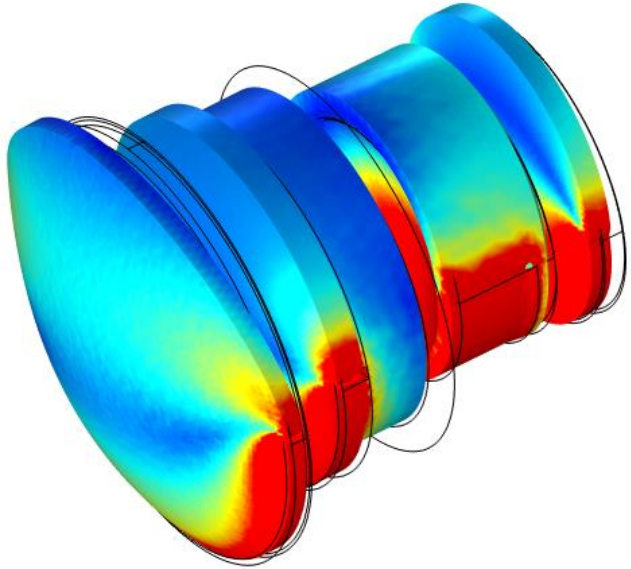


Image @ No deformation

Image @ 1[mm] max deformation

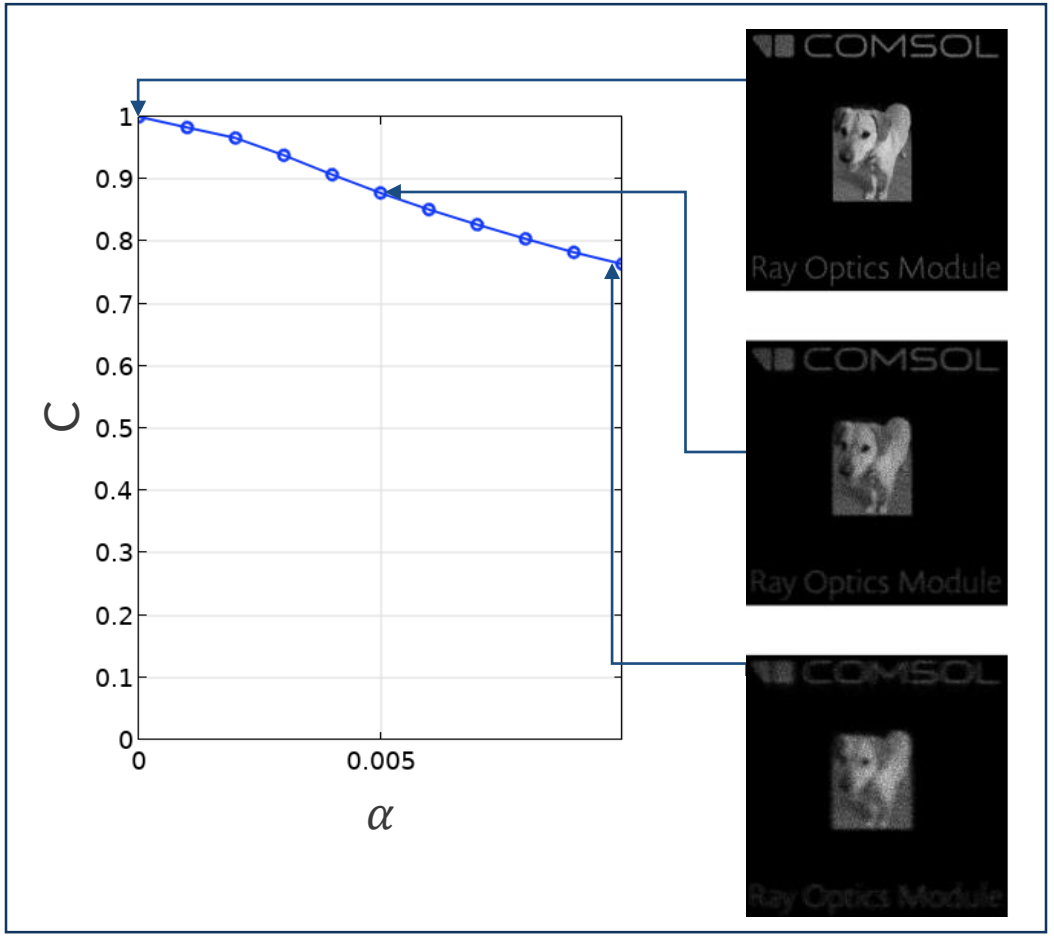
Image @ 2[mm] max deformation

Image simulation result and a correlation example

Introducing normalized strain α (proportional to temperature increase)

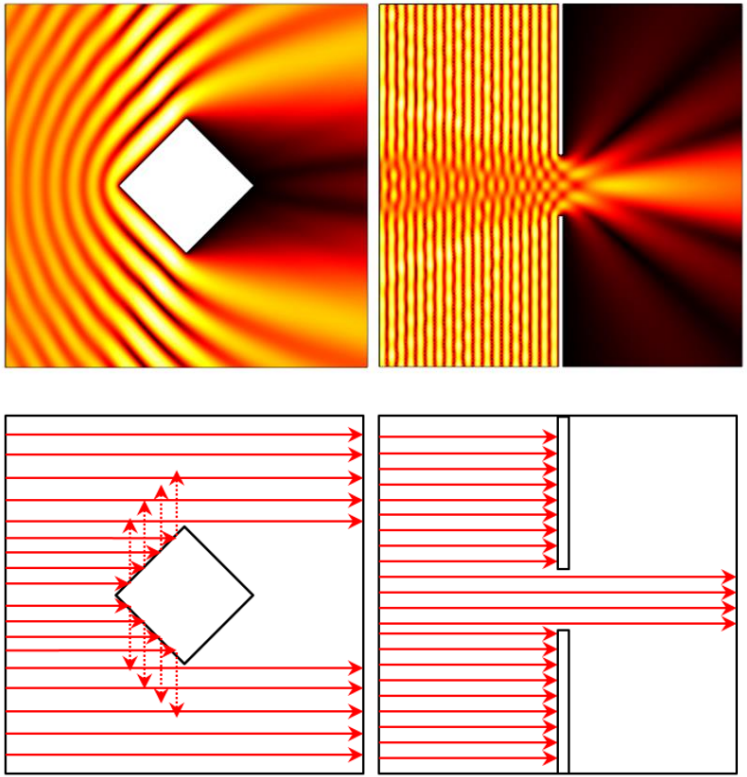
Define correlation integral C as

$$C=\frac{\int f(\alpha)f(0)}{\int f^2(0)}$$



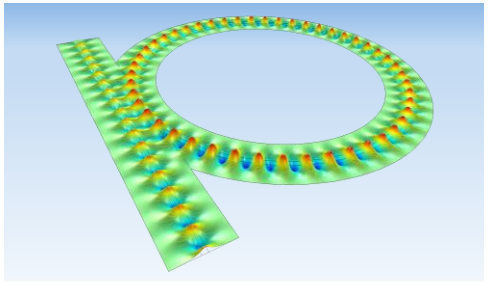
Model evolutions: Ray Optics vs. Full Wave

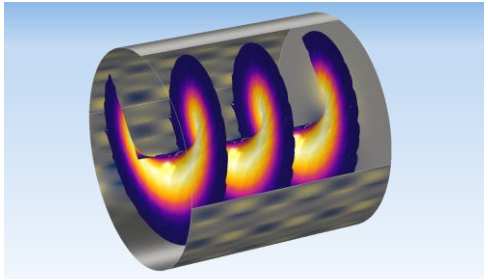
- RF or Wave Optics
  - Full-wave formulation is required to model propagation around small objects
  - Use when the geometry is a few wavelengths on each side
  - Diffraction patterns appear around small obstructions or through narrow apertures
- Ray Optics
  - Ray paths are not strictly solutions to a wave equation
  - Diffraction is not included

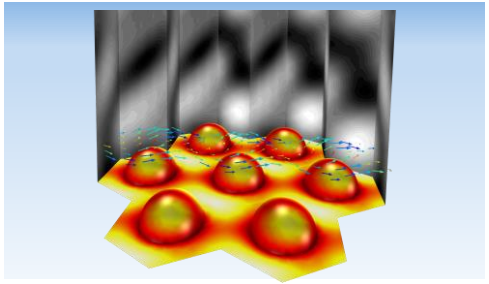


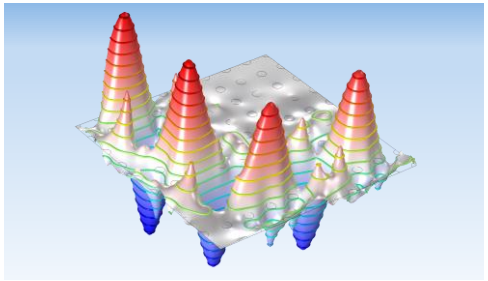
Full suite for Wave Optics simulations

- Integrated optics, Fiber optics, Nonlinear optics, Optical scattering, Lasers



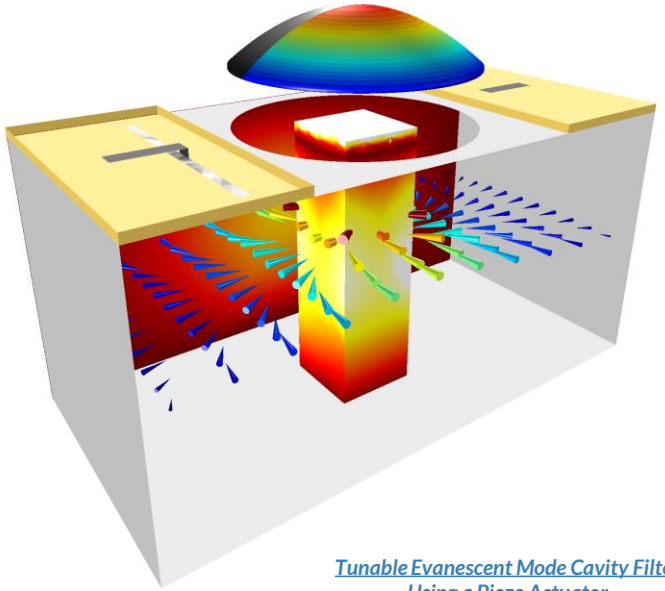






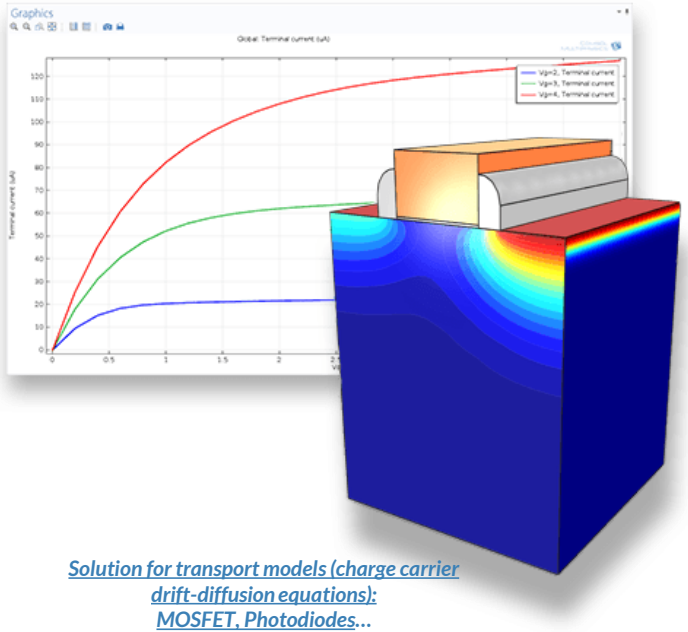
Additional Modules for Electromagnetics devices

MEMS Module



Tunable Evanescent Mode Cavity Filter Using a Piezo Actuator

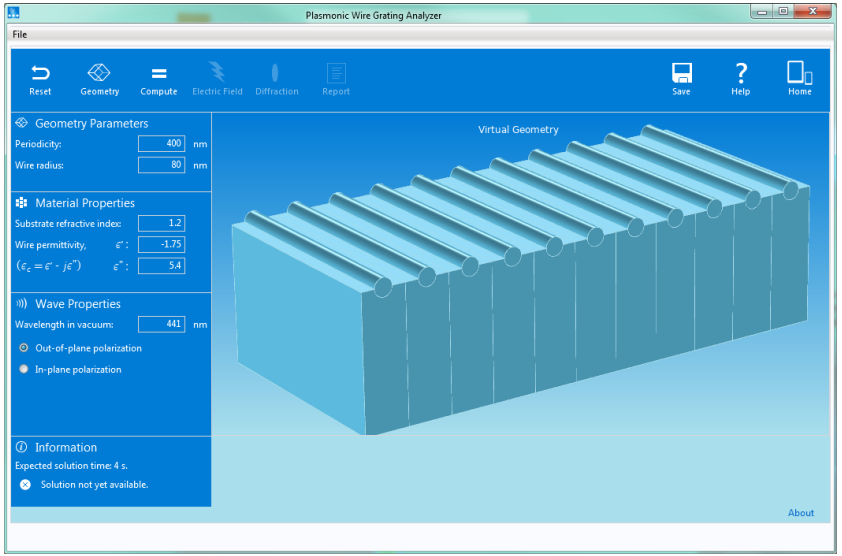
Semiconductor Module



Solution for transport models (charge carrier drift-diffusion equations): MOSFET, Photodiodes…

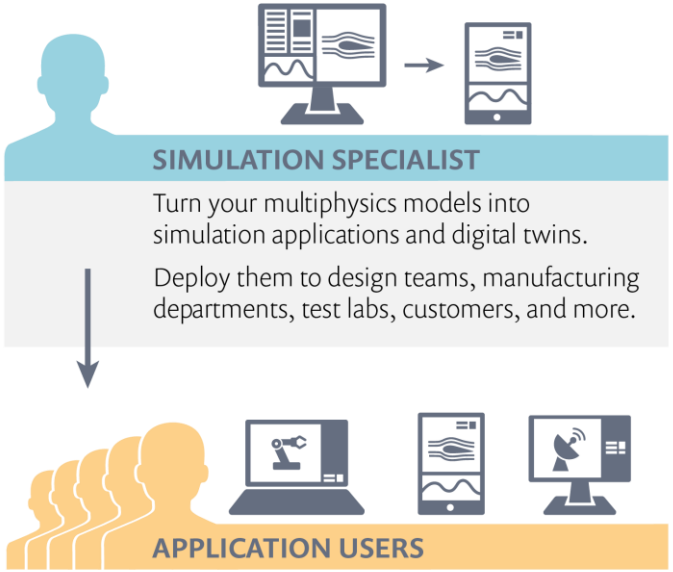
Plasmonic Wire Grating Analyzer

- Simple and easy to use GUI for desktop, tablet, and smartphone
- Diffraction efficiencies for the transmitted and reflected waves (m = 0) and the first and second diffraction orders (m = ±1 and ±2)
- Electric field norm
- Incident wave vector and wave vectors for all reflected and transmitted modes



Deployment

- COMSOL Compiler™
  - Create standalone executable files which do not require purchase of licenses to run
- COMSOL Server™
  - Give your organization access to applications and manage them using administrator tools



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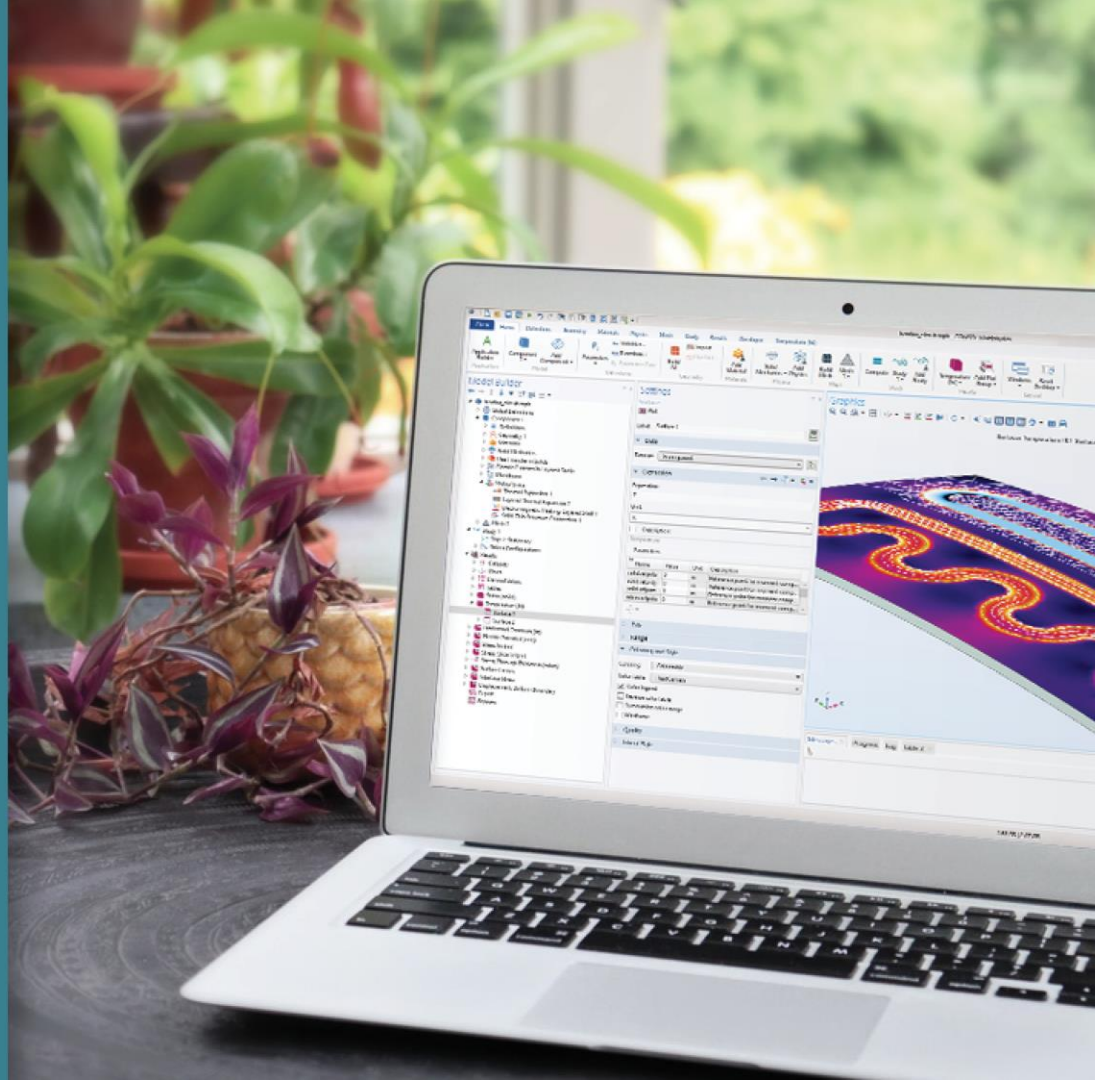
- Discuss your simulation needs
- Request a software demonstration
- Get personalized resource recommendations



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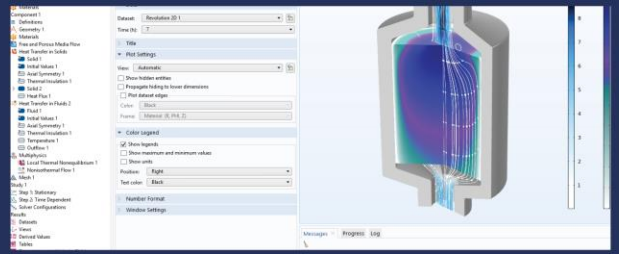

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Ask your toughest modeling questions to members of COMSOL's technical staff

MINICOURSES

Learn how to use the COMSOL Multiphysics® software in core, introductory, and advanced sessions

OTHER EVENTS

- Keynote talks
- Panel discussions
- 1-1 support sessions
- User presentations
- Exhibition