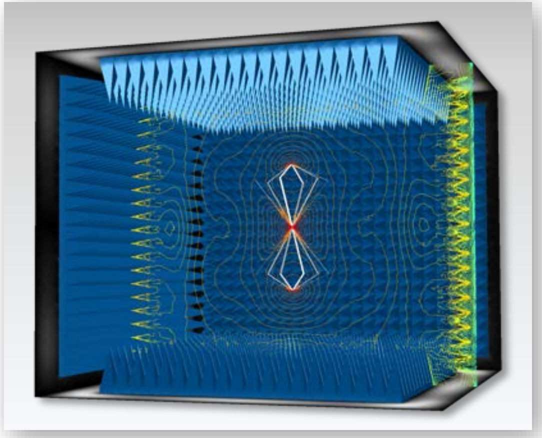
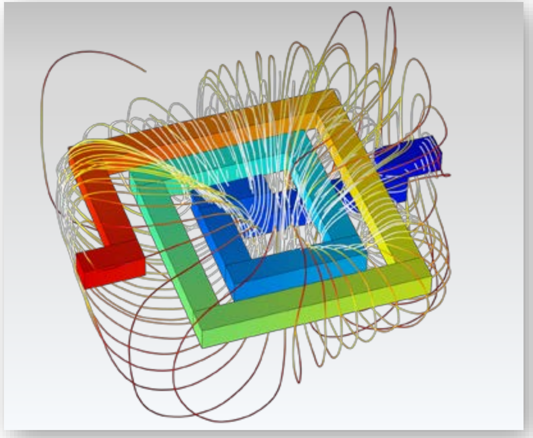
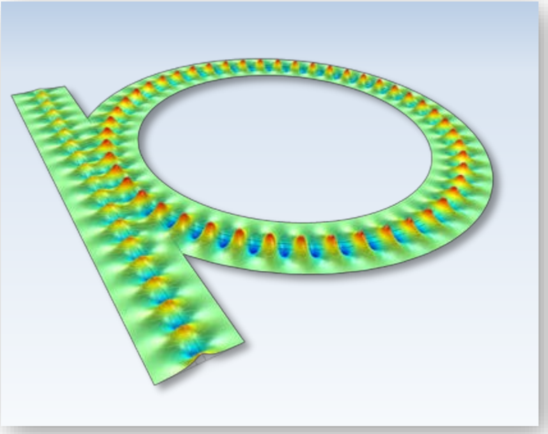
COMSOL CONFERENCE 2015 BOSTON

Best Practices in EM Simulation in COMSOL Multiphysics







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Presenters

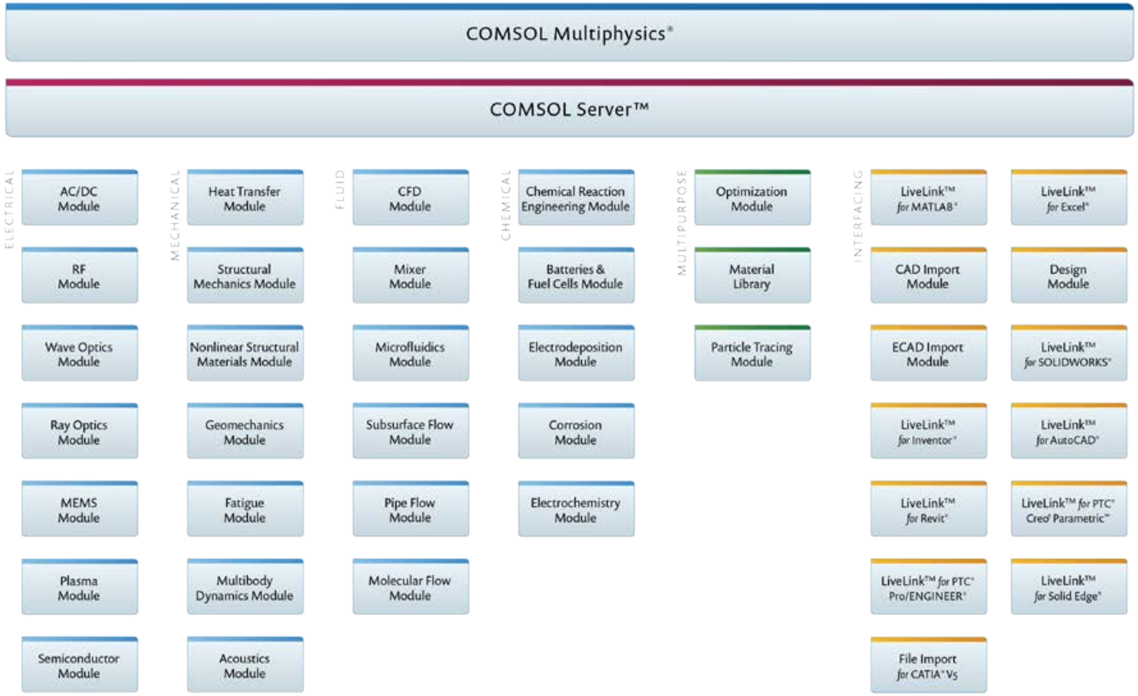
Control the poly-dispersed droplet breakup mode inside a microfluidic flow-focusing device by external electric field

Yuehao Li* and Prof. K. Nandakumar
EPIC Center
Louisiana State University

Simulating Plasmon Effect in Nanostructured OLED Cathode Using COMSOL Multiphysics

Leiming Wang
Konica Minolta Laboratory USA Inc.

Product Suite – COMSOL® 5.2



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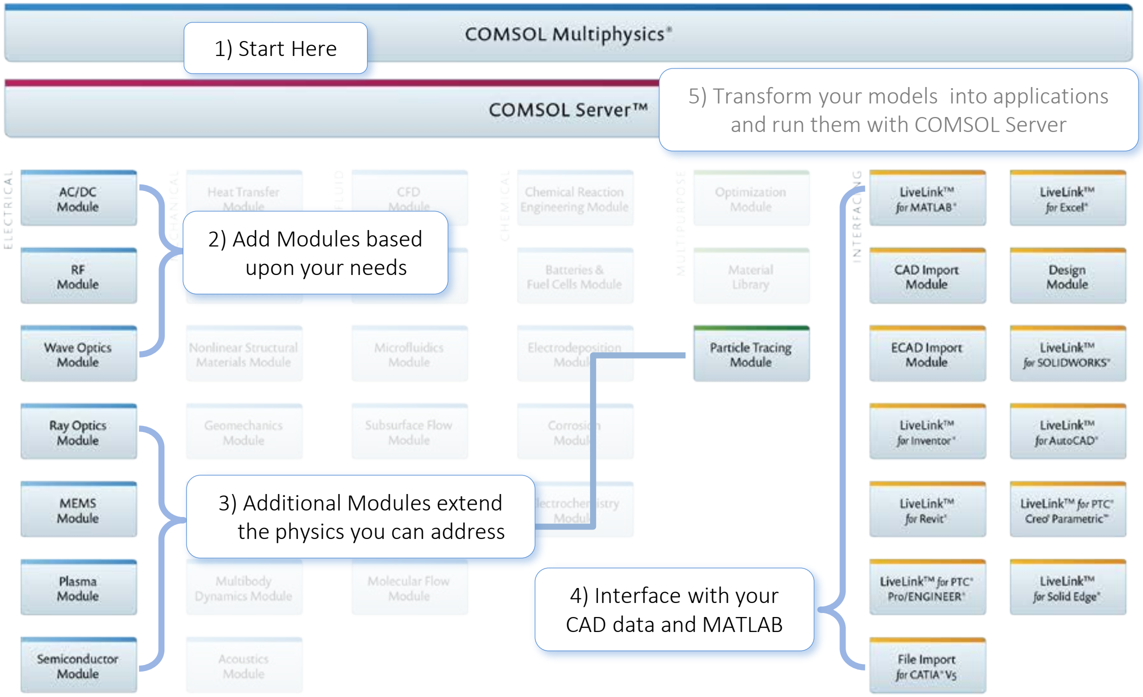
Electromagnetics is Extended by Add-on Modules



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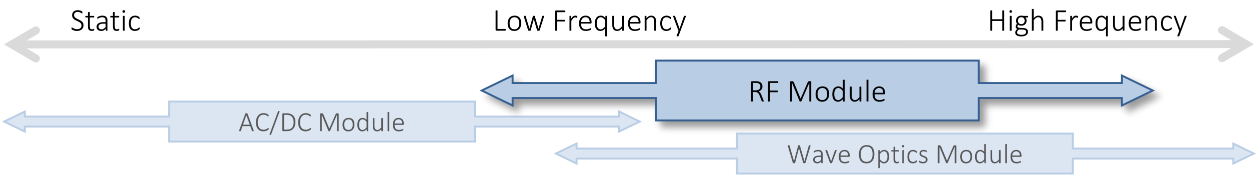
Frequency coverage



- What is “high frequency”?
- Linear/nonlinear/dispersive models?

Formulations per Module

COMSOL Multiphysics[1]	RF Module	Wave Optics Module	AC/DC Module
Static Electric Currents Static Joule Heating Electrostatics Magnetic Fields[2]	Electromagnetic Waves - Frequency Domain - Time Explicit - Transient Microwave Heating Transmission Line Equations Electrical Circuits	Electromagnetic Waves - Frequency Domain - Time Explicit - Transient - Beam Envelopes Laser Heating	Electric Currents in Solids Electric Currents in Shells Joule Heating Electrostatics Magnetic Fields Induction Heating Magnetic and Electric Fields Magnetic Field Formulation Rotating Machinery Electrical Circuits

[1] Core package contains a reduced set of boundary conditions for these formulations
[2] 2D and 2D-axisymmetric geometries and static and frequency domain formulations only

Maxwell's Equations

$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

- Maxwell-Ampere's law

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

- Faraday's law

$$\nabla \cdot \mathbf{D} = \rho$$

- Gauss' law, electric

$$\nabla \cdot \mathbf{B} = 0$$

- Gauss' law, magnetic

$$\nabla \cdot \mathbf{J} = -\frac{\partial \rho}{\partial t}$$

- Equation of continuity

FAQ

- What is the definition of voltage?
- What is the definition of “ground”?
- On the use of analytical solutions
- Initial conditions for time domain simulations
- Open boundaries, PMLs, radiation conditions

Voltage

- In DC, electric and magnetic fields are one-way coupled:
- **E**$=-\nabla V \rightarrow$ **J**$=\sigma$**E** $\rightarrow$ **B** (Ohm's Law + Ampère's Law)
  - Voltage = *potential difference*
- In AC, the alternating **B** field contributes to **E.** Faraday's Law: ∇x**E** $=$ -d(**B**)/dt $\Rightarrow$ **E** $\neq -\nabla V$
- In AC inductive/EM field modeling "voltage" is not the same as "potential difference"!

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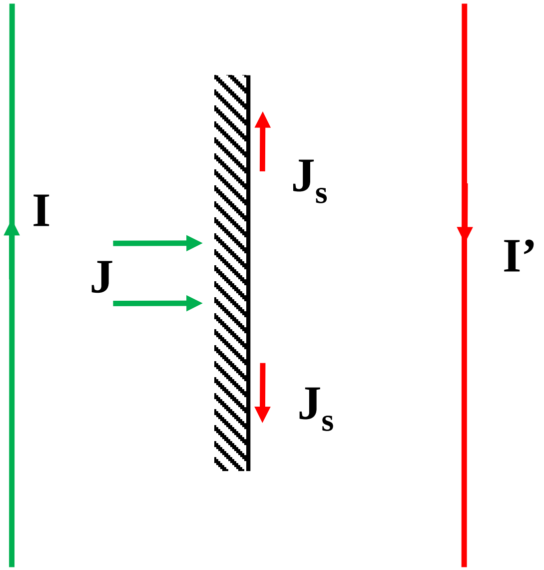
“Ground” in EM (inductive) models

Magnetic Insulation
or PEC
$\mathbf{n}\mathrm{x}\mathbf{A} = 0 \Leftrightarrow \mathbf{n}\bullet\mathbf{B} = 0$
or
“$\mathbf{n}\mathrm{x}\mathbf{E} = 0$”



- Models highly conductive media, with no losses.
- Zero-impedance condition – allows for return currents / induced surface currents
- Used to model ”ground planes” and ”anti symmetry”

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Analytical solutions

Can give artifacts in models:

- Mesh convergent
  - Analytical vs. numerical ports
  - “Discrete divergence” of source currents
- Inconsistent
  - Applicability of Biot-Savart formula
  - Approximations

Initial Conditions

- Computed static solution as IC
  - Nonlinear/iterative solver
- Charge relaxation modeling
  - Consistent initial charges required

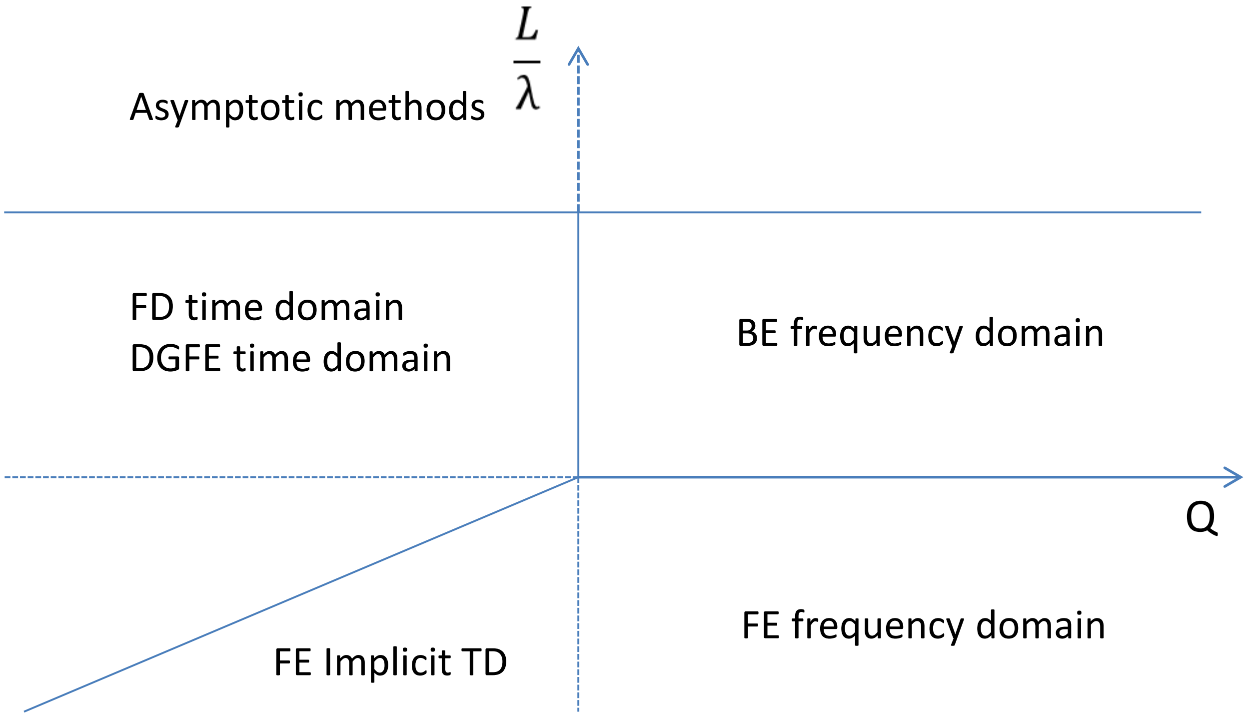
Open boundaries

- Radiation/infinity vs. symmetry boundaries
- Tailoring PMLs
  - Meshing
  - Scaling
  - Advanced methods – Scaling System

Technology in the works

- Nodal discontinous Galerkin (DG)
  - Time Domain EM Waves
- Integral Equations / Boundary elements
  - Statics and Waves

Methods for EM problems



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