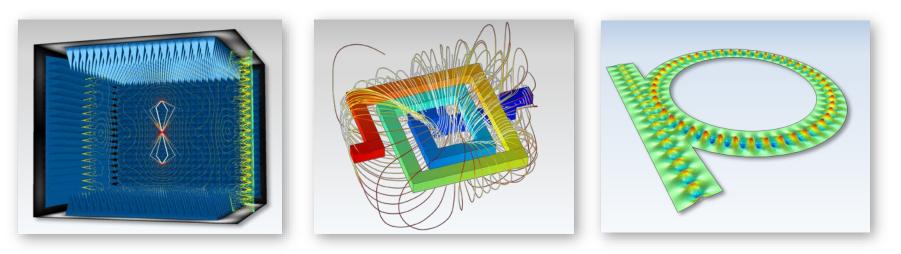


Best Practices in EM Simulation in COMSOL Multiphysics



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Presenters

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

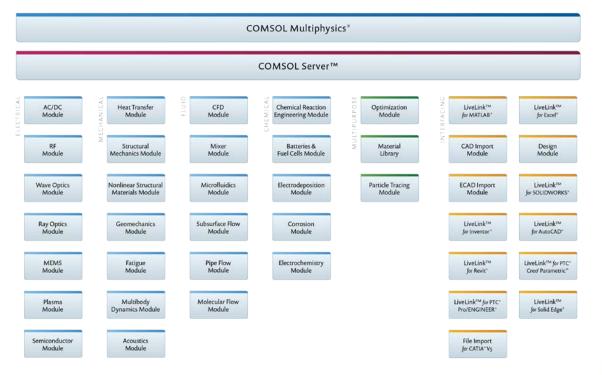
Yuehao Li* and Prof. K. Nandakumar EPIC Center Louisiana State University

Simulating Plasmon Effect in Nanostructured OLED Cathode Using COMSOL Multiphysics

Leiming Wang Konica Minolta Laboratory USA Inc.



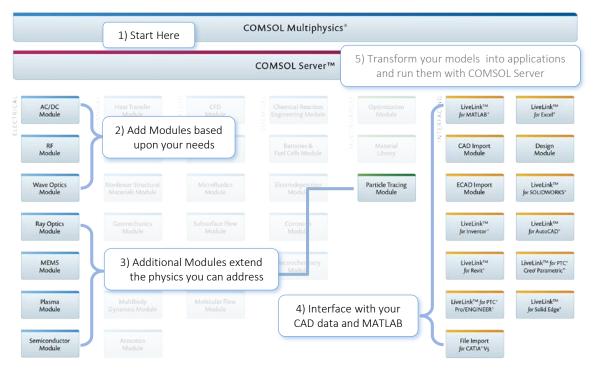
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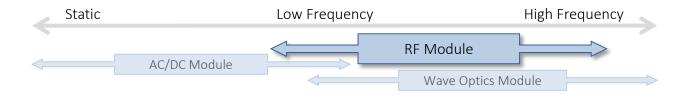
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Electromagnetics is Extended by Add-on Modules



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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

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

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

$$abla \cdot \mathbf{D} =
ho$$

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

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

- Maxwell-Ampere's law
- Faraday's law
- Gauss' law, electric
- Gauss' law, magnetic
- 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

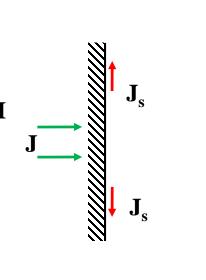
- In DC, electric and magnetic fields are one-way coupled:
- $E = -\nabla V \rightarrow J = \sigma E \rightarrow B$ (Ohm's Law + Ampère's Law) - Voltage = *potential difference*
- In AC, the alternating **B** field contributes to **E**. Faraday's Law: $\nabla x \mathbf{E} = -\mathbf{d}(\mathbf{B})/\mathbf{dt}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



"Ground" in EM (inductive) models

I'

Magnetic Insulation or PEC $\mathbf{nxA} = 0 \Leftrightarrow \mathbf{n} \cdot \mathbf{B} = 0$ or " $\mathbf{nxE} = 0$ "



•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"





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

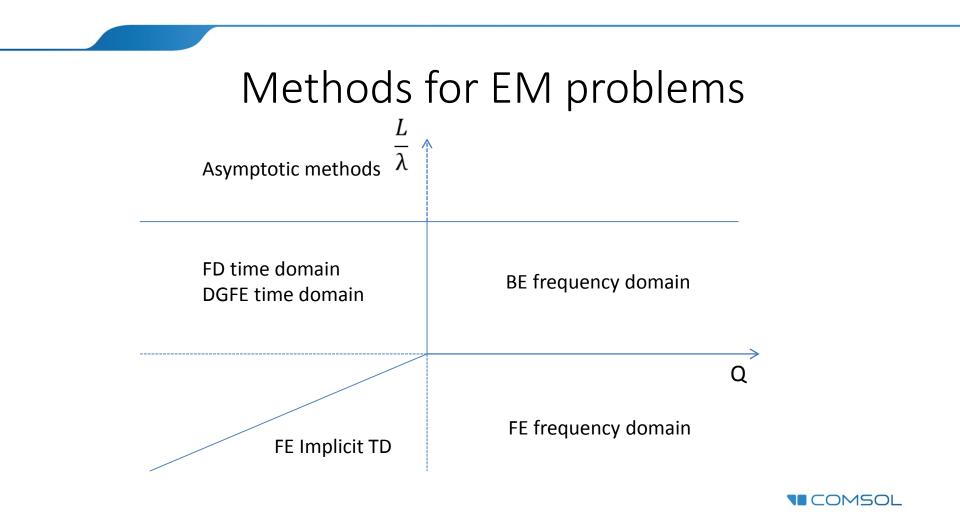
- Radiation/infinity vs. symmetry boundaries
- Tailoring PMLs
 - Meshing
 - Scaling
 - Advanced methods Scaling System



Technology in the works

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





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