Finite Difference Time Domain (FDTD) Simulator

Informative session

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May 10, 2025

Overview

Table of Contents

Salient features

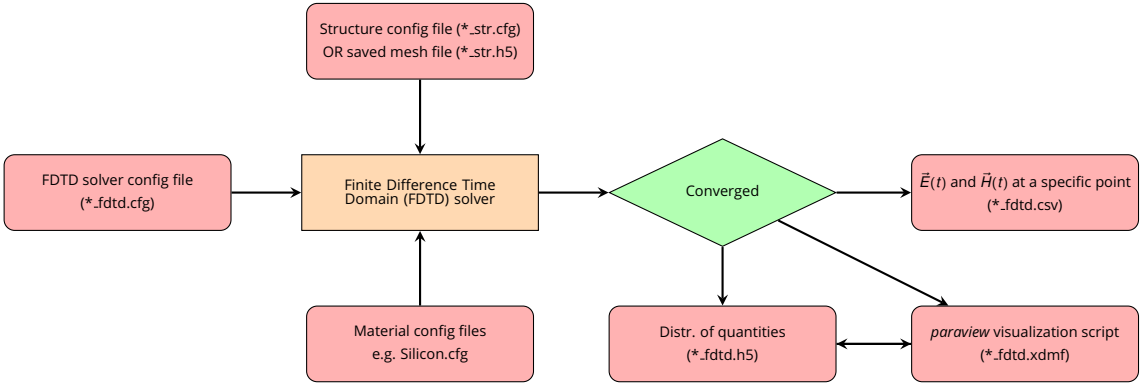
The FDTD solver takes the config file with the required solver inputs and calculates time evolution of electromagnetic waves using finite-difference-time-domain method.

Salient features –

- Materials with wavelength dependent real and imaginary permittivity,
- Dispersive material models – Drude, Debye, Lorentz, and Kerr models.
- Use plane-wave source with uniform beam, Gaussian beam, or mode-beam, also dipole source.
- Apply BCs – reflective, periodic (+ oblique incidence), PML
- *built-in hardware acceleration enabled*.

Table of Contents

FDTD solver interface and config files



To run a FDTD solver simulation...

- Create and save *FDTD solver config file*, *structure config or mesh file*, *material files* (if modified) in the same folder.
- Run simulations using the following command –
  `>> fdtdsolver fdtdsolver SiWG_fdtd.cfg`
- To use *hardware acceleration*, use the following command –
  `>> fdtdsolver gpufdtdsolver SiWG_fdtd.cfg`

Easy-to-use Config file

```
File: {
  Device = "fdtdSiWG_str.cfg";
  Out = "SiWG";
}

Solver: {
  MaximumTime = 15E-14;
  GridType = "TM";
  Settings = ["WavelengthDepIndex"];
}

Source*left: {
  Type = "PlaneWave";
  BeamShape = "ModeBeam";
  Position: ([-0.6, -0.2, 0.], [-0.6, 0.2, 0.]);
  Theta = 90;  Phi = 0; Wavelength = 0.3;
  EffectiveIndex = 3.5; NRise = 5;
  Intensity = 1000; Delay = 1;
  Flags = ["UsePowerMethodModeSolver"];
}

Boundary*xbdr: {
  Axis = ["Xmin", "Xmax"];
  Model = "CPML"; PMLLayers = 20.;
}

Boundary*ybdr: {
  Axis = [ "Ymin", "Ymax", "Zmin", "Zmax"];
  Model = "CPML"; PMLLayers = 20.;
}
```

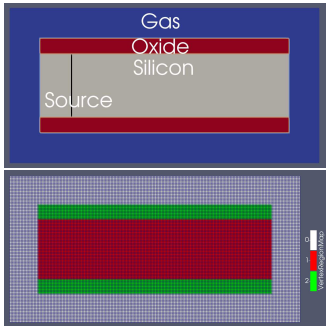


Figure: Structure of the simulated waveguide

- Include a new device structure.
- Define the source window.
- Apply specific boundary conditions.
- Set solver parameters.

Modeling dispersive materials

```
Dispersive*Si: {
  Region = "RegSi";
  Model = "Drude";
  NumberPoles = 3;
  PoleFreq = [2.31E15, 2.18E15, 2.08E15];
  DampFact = [5.5E12, 4.353E12, 10.88E12];
}
```

- `Dispersive`: Defines a dispersive model for `RegSi` region.
- `Model`: Specifies model which has `NumberPoles`.
- `PoleFreq` and `DampFact`: Parameters corresponding each pole are set as lists.
- Dispersive materials are modeled by "Auxiliary Differential Equation" method.

$$\chi(\omega) = \frac{\omega_p^2}{j\omega \cdot (j\omega + g)} \tag{1}$$

$$\vec{P}(\omega) = \epsilon_0 \chi(\omega) \cdot \vec{E}(\omega) \tag{2}$$

$$\vec{\Phi} = j\omega \vec{P}(\omega) = \frac{\epsilon_0 \omega_p^2}{(j\omega + g)} \vec{E}(\omega) \tag{3}$$

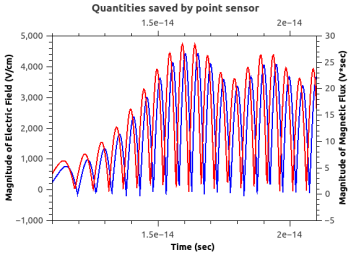
Substituting $j\omega \rightarrow \frac{\partial}{\partial t}$,

$$g\vec{\Phi} + \frac{\partial \vec{\Phi}}{\partial t} = \epsilon_0 \omega_p^2 \vec{E} \tag{4}$$

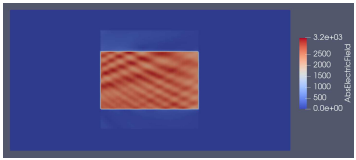
Results Visualization

```
Movie*XYEField: {
  Size = "640x480"; Plane = "XY";
  Intercept = 0; Quantities = ["ElectricFieldZ"];
}

PointSensor*X0pt: {
  Position = [0.05, 0.025, 0.];
  Quantities = ["AbsElectricField", "AbsMagneticFlux"];
}

TimeAverage*AvgMid: {
  TimeBegin = 2E-15; TimeEnd = 4E-15;
  Quantities = ["AbsElectricField", "AbsMagneticFlux"];
  Position = ([-0.35, -0.35, 0.], [0.35, 0.35, 0.]);
  TimeSteps = 1;
}
```

- `Pointsensor`: Saves temporal data at given point in a csv file.
- `Movie`: Saves temporal data at the cross-section as a movie.
- `TimeAverage`:Stores temporal average of the data.
- Saves an *xdmf* script for visualization in *paraview*.



(a) Data of Point Sensor



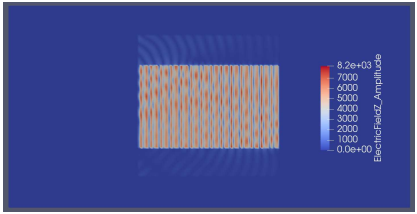
(b) Time average of $|\vec{E}|$

Figure: Magnitude and Phase of E_z

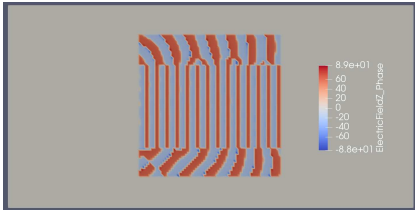
Results Visualization

```
PhaseCalculator*Ph: {
  Time = 2E-15;
  Quantities = ["ElectricFieldZ", "MagneticFluxZ"];
  Position = ([-0.35, -0.35, 0.], [0.35, 0.35, 0.]);
}

Detector*det: {
  StepX = 5;  StepY = 5; StepZ = 5;

  Tolerance = 1E0; StartTime = 2E-15;
  Position = ([-0.35, -0.35, -0.26], [0.35, 0.35, 0.26]);
  Quantities = ["ElectricFieldZ"];
}
```

- `PhaseCalculator`: Calculates magnitude and phase of the data at a time-point. Also, saves an *xdmf* script for visualization in *paraview*.
- `Detector`: Checks if the given quantity has stabilized over time. When yes, stops the simulation.



(a) Magnitude of Electric Field



(b) Phase of Electric Field

Figure: Magnitude and Phase of E_z

Conclusions

- Finite-difference time domain (FDTD) solver supports,
  - Materials with wavelength dependent real and imaginary permittivity,
  - Dispersive material models – Drude, Debye, Lorentz, and Kerr models.
  - Use plane-wave source with uniform beam, Gaussian beam, or mode-beam, also dipole source.
  - Apply BCs – reflective, periodic (+ oblique incidence), PML
- Hardware acceleration enabled in FDTD calculations.
- Open to collaborations with our customers / partners.

Table of Contents

Easy-to-install licenses

For ordering a license, along with the name and the organization details, please also provide –

- For the node-locked licenses: Ethernet mac address of the client machine on which the software will run.
  OR
- For the server licenses: Ethernet mac address of the server machine at the client organization.

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The End

Questions? Comments?