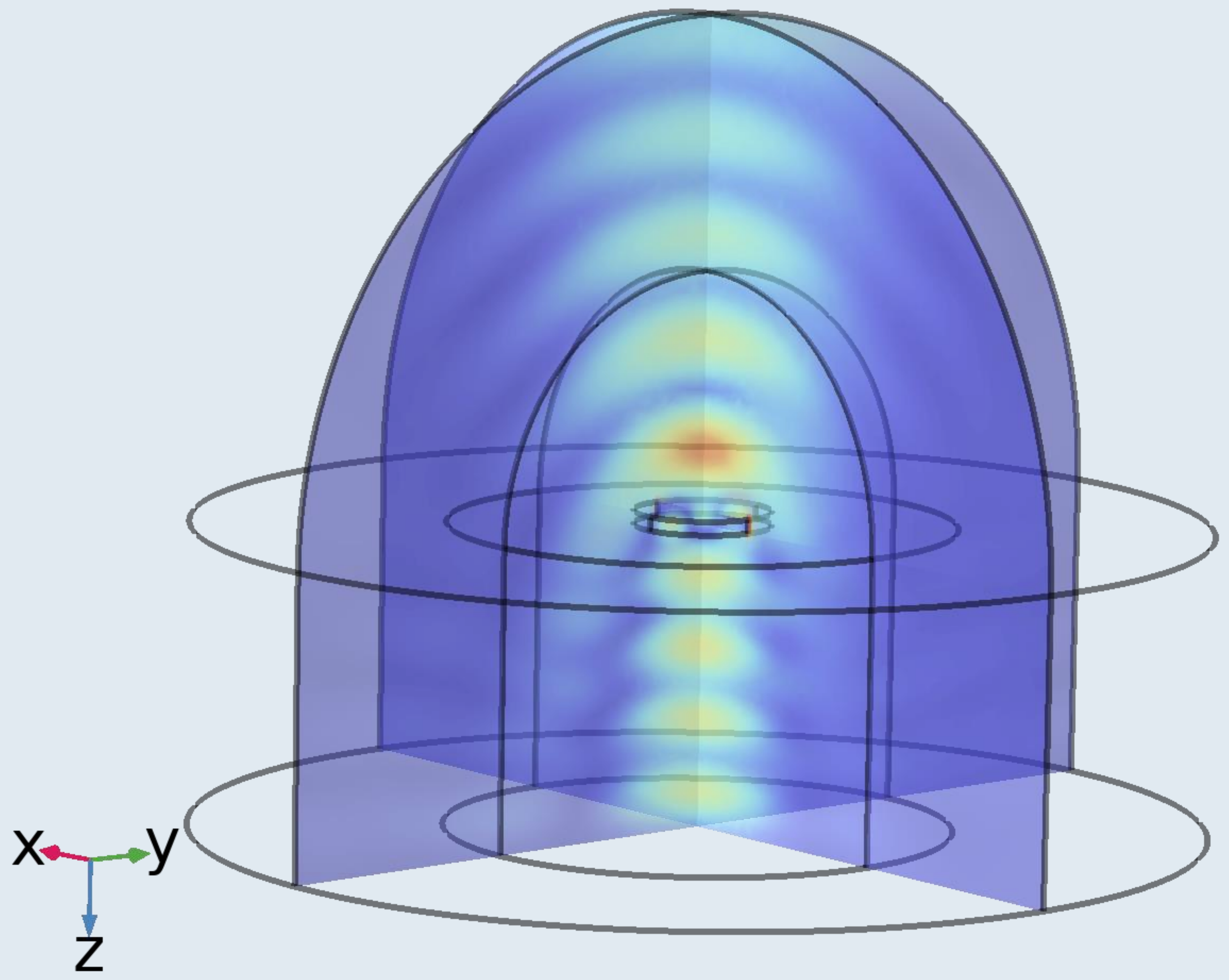

Third Harmonic Generation from multilayer Van der Waals nanophotonic structure

Design and characterization of nonlinear photonic devices based on thick Van der Waal material transferred on top of a multilayer substrate for nonlinear optical application

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Introduction and Motivation

- Thick Van der Waal material such as Molybdenum Disulphide (MoS_2) is an emerging semiconducting nanomaterial[1,2] for photonics.
- High refractive index from near to mid infrared wavelength (4-5) [Silicon ~ 3.45] (Application :- Bio sensors, Ultrathin lenses)
- Strong nonlinear optical response (Application :- Frequency mixer, Quantum source)
- Modelling of third harmonic generation[3] (THG) process in thin film and disk of a 108nm thick multilayer MoS_2.
- Gaussian wave excitation modelled using Plane Wave Expansion (PWE) method[4]
- Simulation model is simplified using appropriate boundary conditions and by segmentation of the fundamental and THG simulation regions in different area/volume.

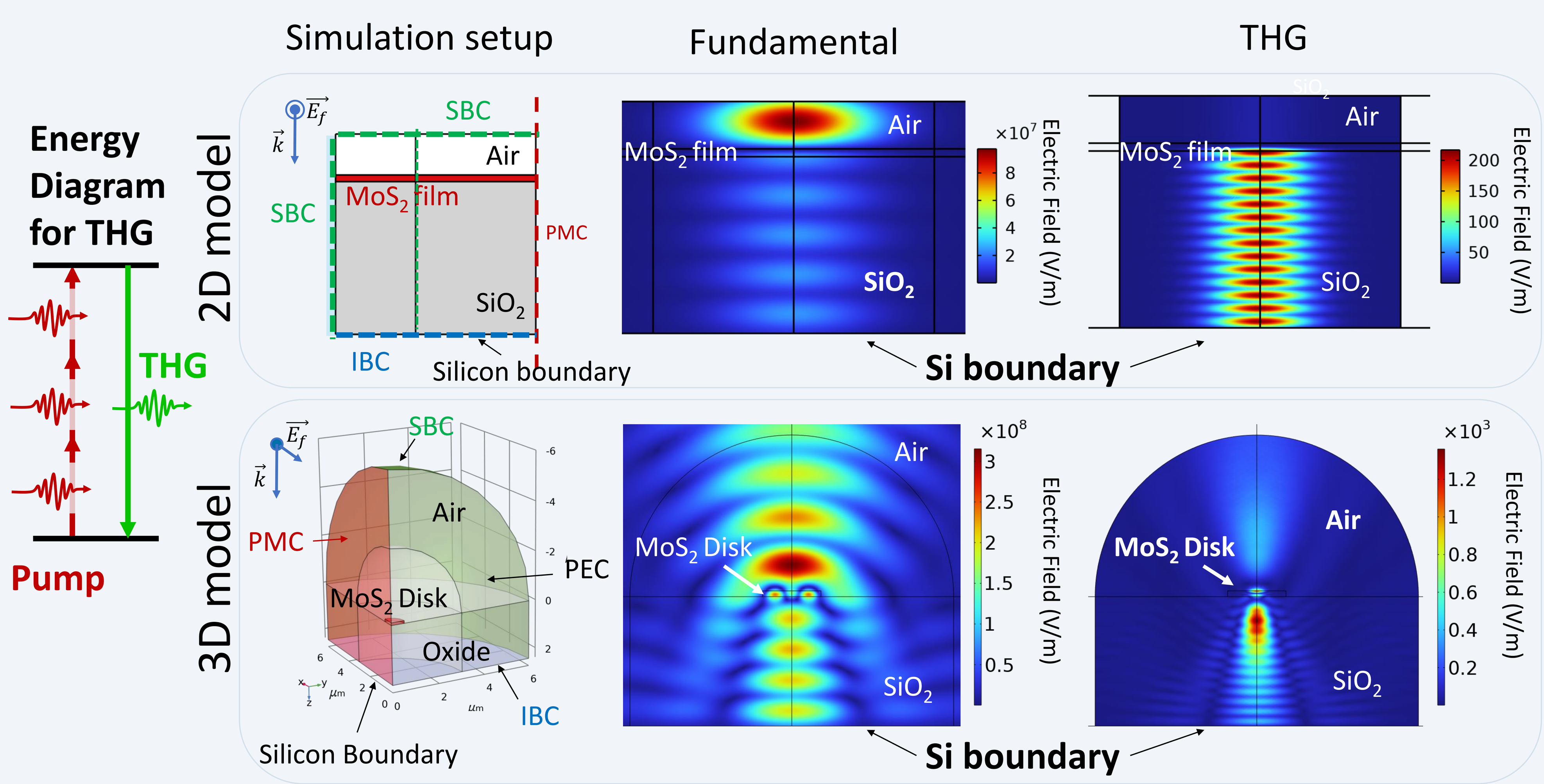

FIGURE 1. Schematic setup for nonlinear simulation, Fundamental and THG field profile for THG process in 2D and 3D geometry

THG Simulation Setup

Spatially varying electric fields for the input pump beam is calculated across the simulation region, to solve the nonlinear wave equation at THG frequency ($\omega_h = 3\omega_f$)

Fundamental Field

$$\nabla \times \mu_r^{-1}\left(\nabla \times \vec{E}(\omega_f)\right) - k_0^2\left(\epsilon_r(\omega_f) - j\frac{\sigma}{\omega_f \epsilon_0}\vec{E}(\omega_f)\right) = 0$$

Third Harmonic Field

$$\nabla \times \mu_r^{-1}\left(\nabla \times \vec{E}(\omega_h)\right) - k_0^2\left(\epsilon_r(\omega_h) - j\frac{\sigma}{\omega_h \epsilon_0}\vec{E}(\omega_h)\right) = \omega_h^2 \mu_0 \overrightarrow{P^{(3)}}(\omega_h)$$

Nonlinear Polarization

$$\overrightarrow{P^{(3)}}(\omega_h) = \epsilon_0 \chi^{(3)} \vec{E}(\omega_f)^3$$

PMC :- Perfect Magnetic Conductor
PEC :- Perfect Electric Conductor
SBC :- Scattering Boundary Condition (Second order)
IBC :- Impedance Boundary Condition

Results

- THG is sensitive to SiO_2 thickness
- Film THG simulation is used for the accurate estimation of SiO_2 thickness
- Subsequently, transition to 3D nonlinear simulation for MoS_2 disk.
- Model Validation :- Good agreement between the experimental THG measurement and nonlinear THG simulation is obtained by adjusting the SiO_2 thickness (~2.425µm) as shown in Figure 2

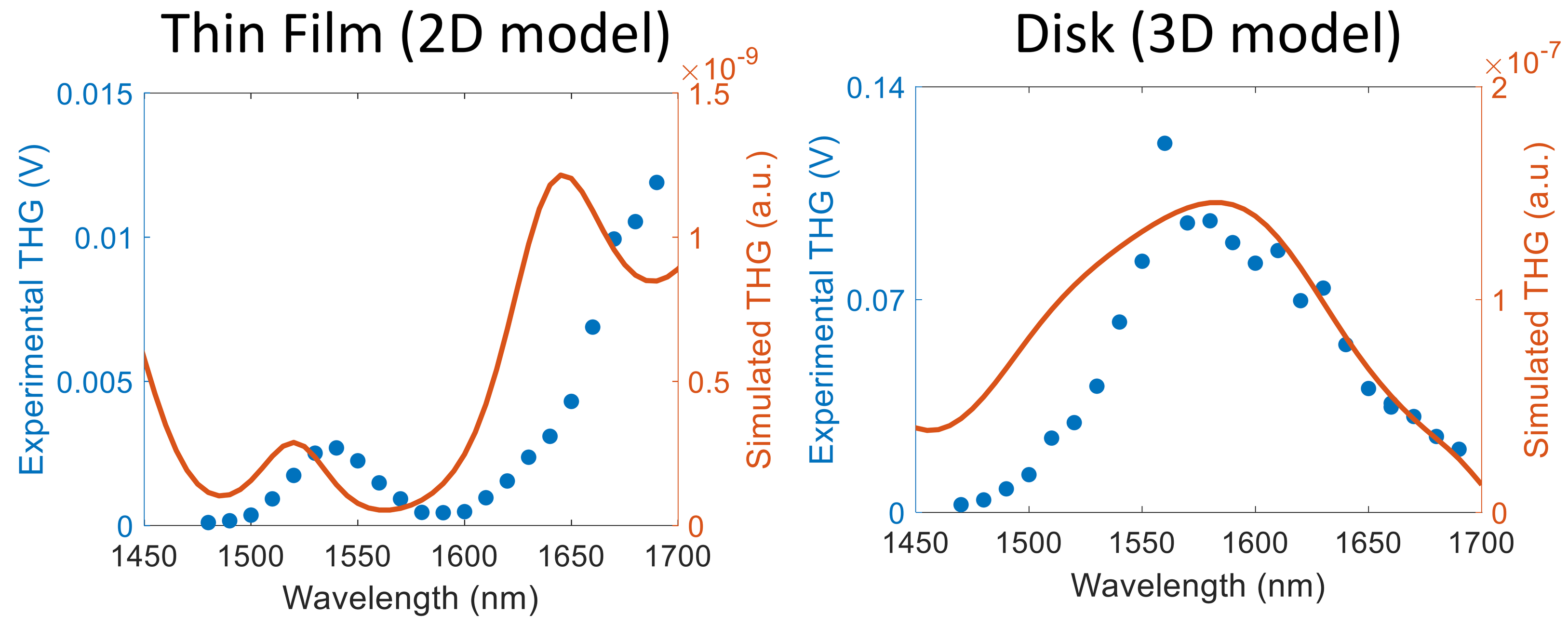

FIGURE 2. Comparison of THG measurement of the fabricated thin film and disk samples with nonlinear THG simulation.

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