COMSOL
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MODELING AND OPTIMIZATION OF TERAHERTZ-PHOTOCONDUCTIVE ANTENNA (THz-PCA)

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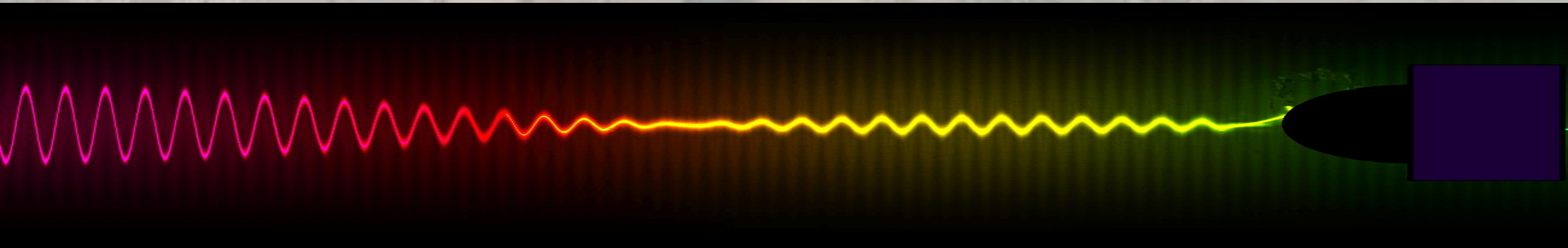

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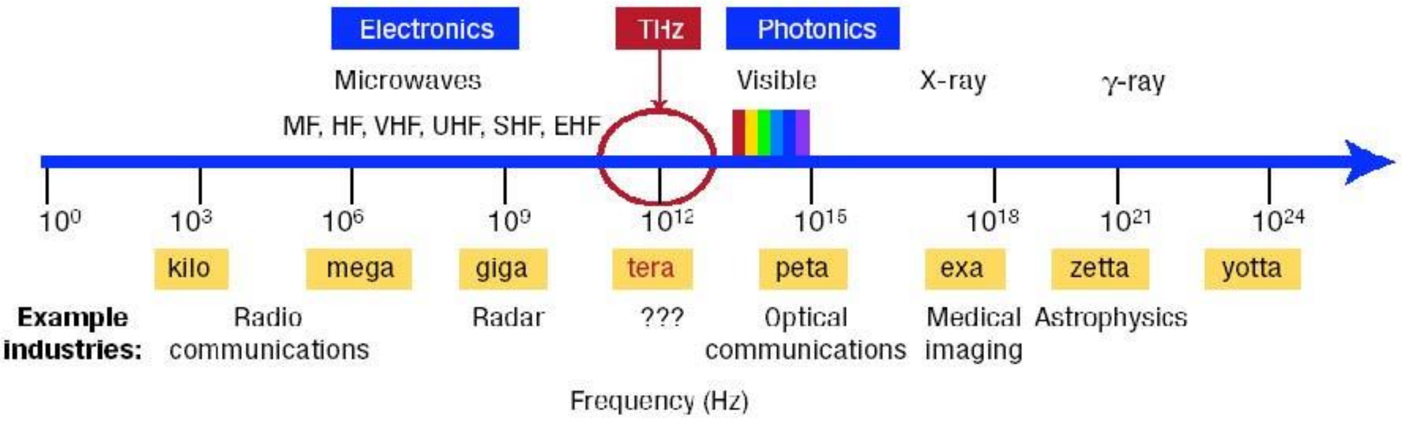
INTRODUCTION



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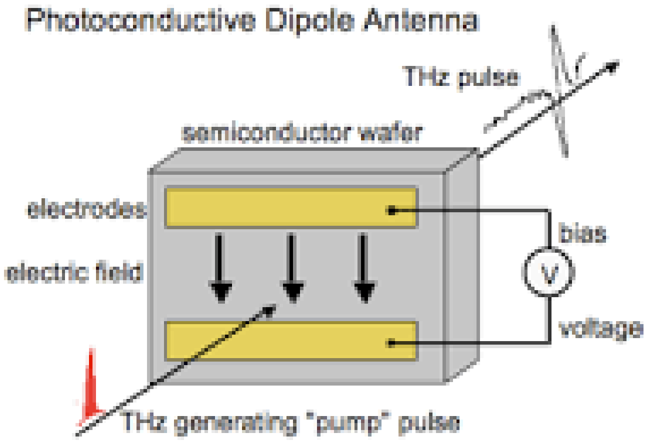

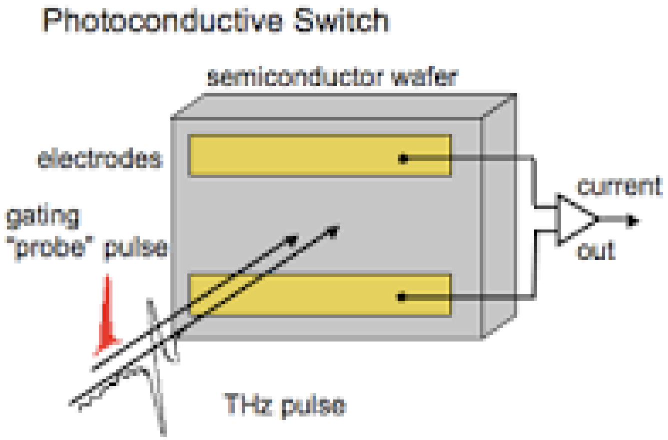

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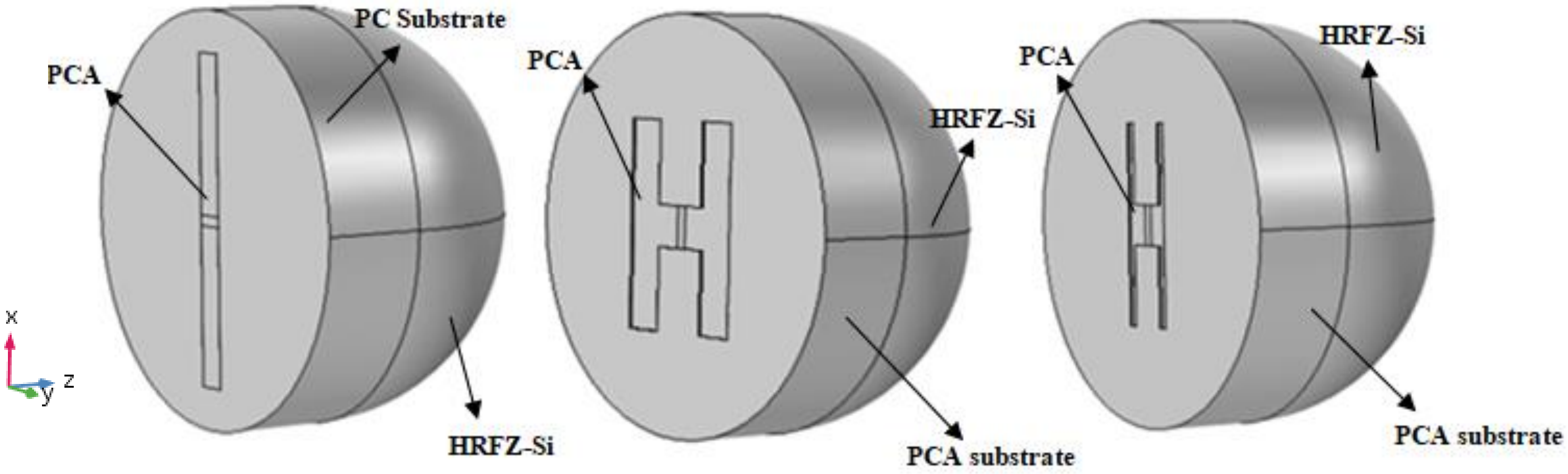
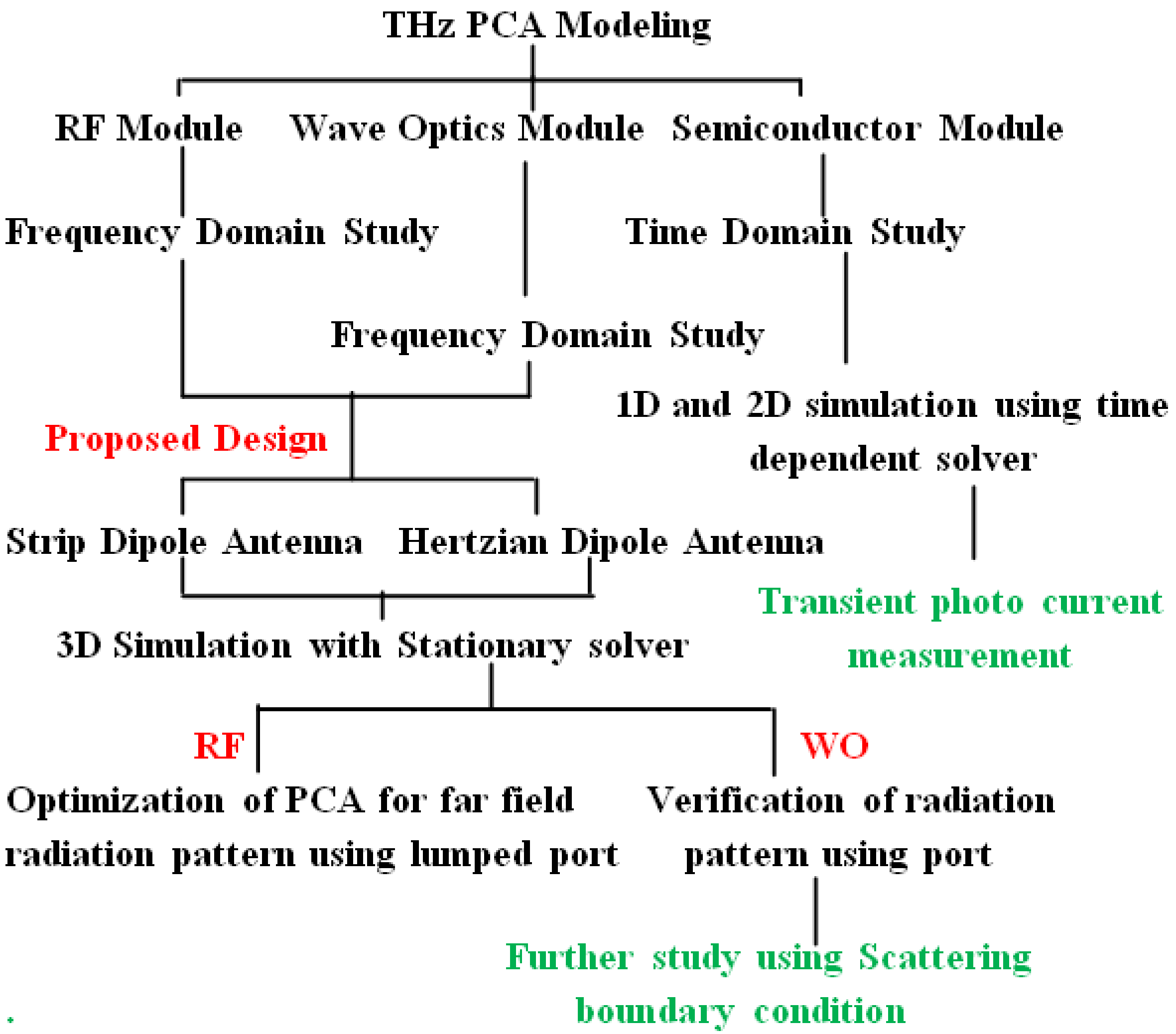
MODELLING OF THZ-PCA



Material Property	Unit (SI)	Au	LT-GaAs	Si	Air
Relative permeability	1	1	1	1	1
Relative permittivity	1	-22.5	12.9	11.7	1
Electrical conductivity	S/m	2400	1000	1.5e-6	1.4e-11

$$E_{THz}(r,t) = -\frac{1}{4\pi\varepsilon_0 c^2}\frac{\partial}{\partial t}\int \frac{J_s\left(r',t-\frac{|r-r'|}{c}\right)}{|r-r'|}\,ds'$$

IMPLEMENTATION WITH COMSOL



THz PCA Modeling

RF Module

Wave Optics Module

Semiconductor Module

Frequency Domain Study

Time Domain Study

Frequency Domain Study

1D and 2D simulation using time dependent solver

Proposed Design

Strip Dipole Antenna

Hertzian Dipole Antenna

Transient photo current measurement

3D Simulation with Stationary solver

RF

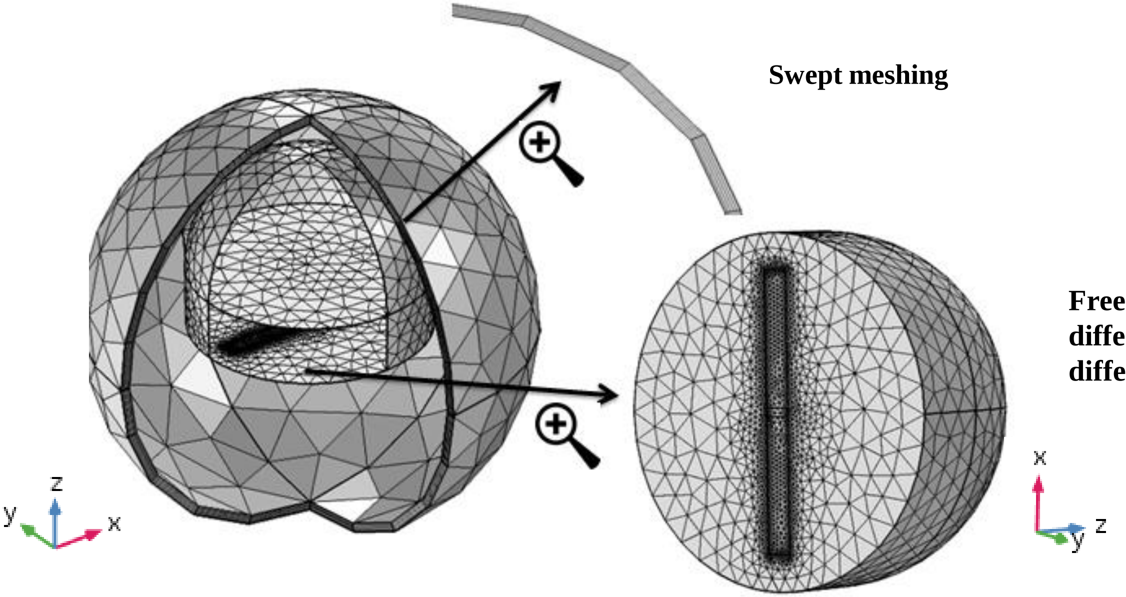
WO

Optimization of PCA for far field radiation pattern using lumped port

Verification of radiation pattern using port

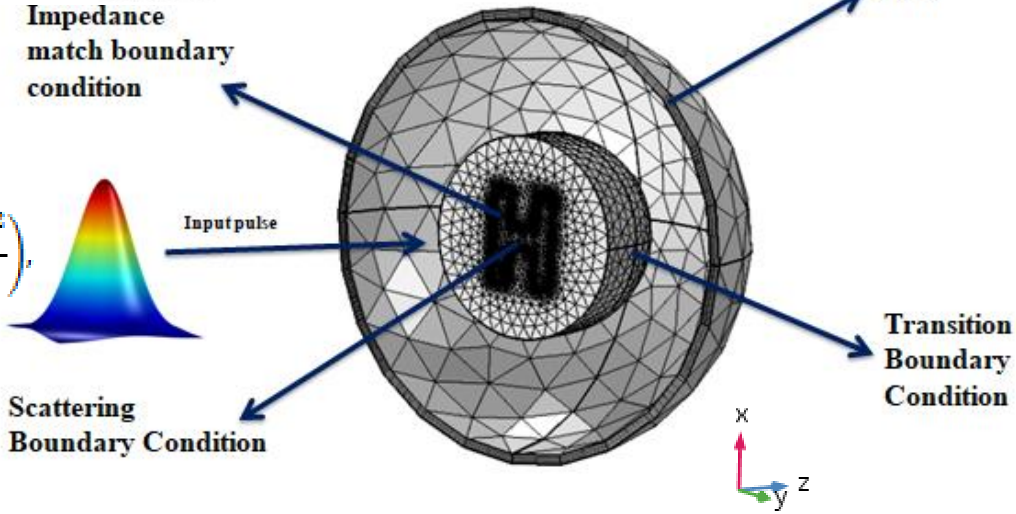
Further study using Scattering boundary condition

MESHING AND BOUNDARY CONDITION



Swept meshing

Free tetrahedral meshing of different size element for three different zone .



Impedance match boundary condition

PML

Transition Boundary Condition

Scattering Boundary Condition

Input Optical Field:

$$E_{inc} = \hat{a}_e E_0 \exp\left(2\ln(0.5)\frac{(x-x_0)^2}{D_x^2}\right)\exp\left(2\ln(0.5)\frac{(y-y_0)^2}{D_y^2}\right),$$

$$E_0 = \sqrt{\frac{P_{ave}8\eta_0}{f_p D_x D_y D_t}}\left(-\frac{\ln(0.5)}{\pi}\right)^{\frac{3}{4}}$$

SIMULATION

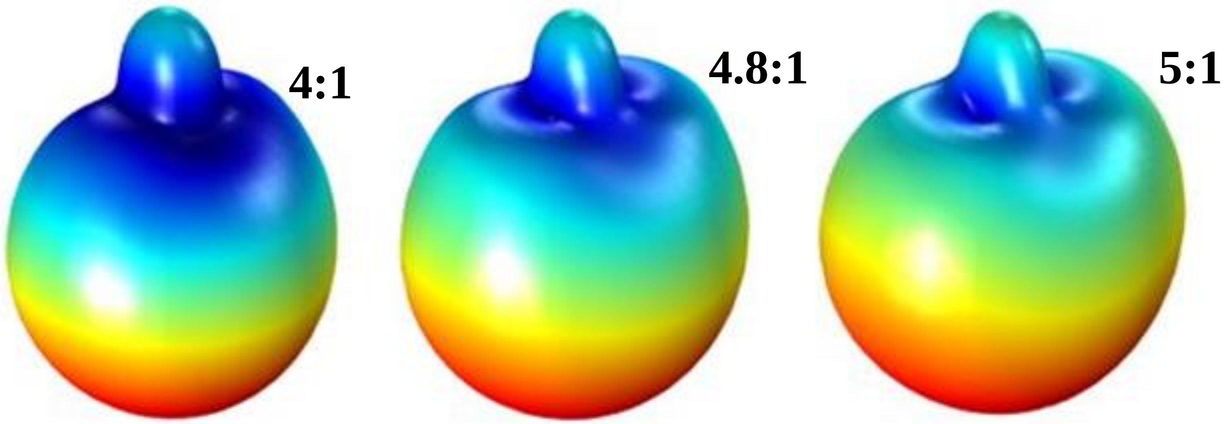
- Optimization
- Optical Response: Solving Maxwell equation using FEM solver
- Electrical Response
- Transient photo-current measurement.

OPTIMIZED RADIATION PATTERN AND PARAMETER:

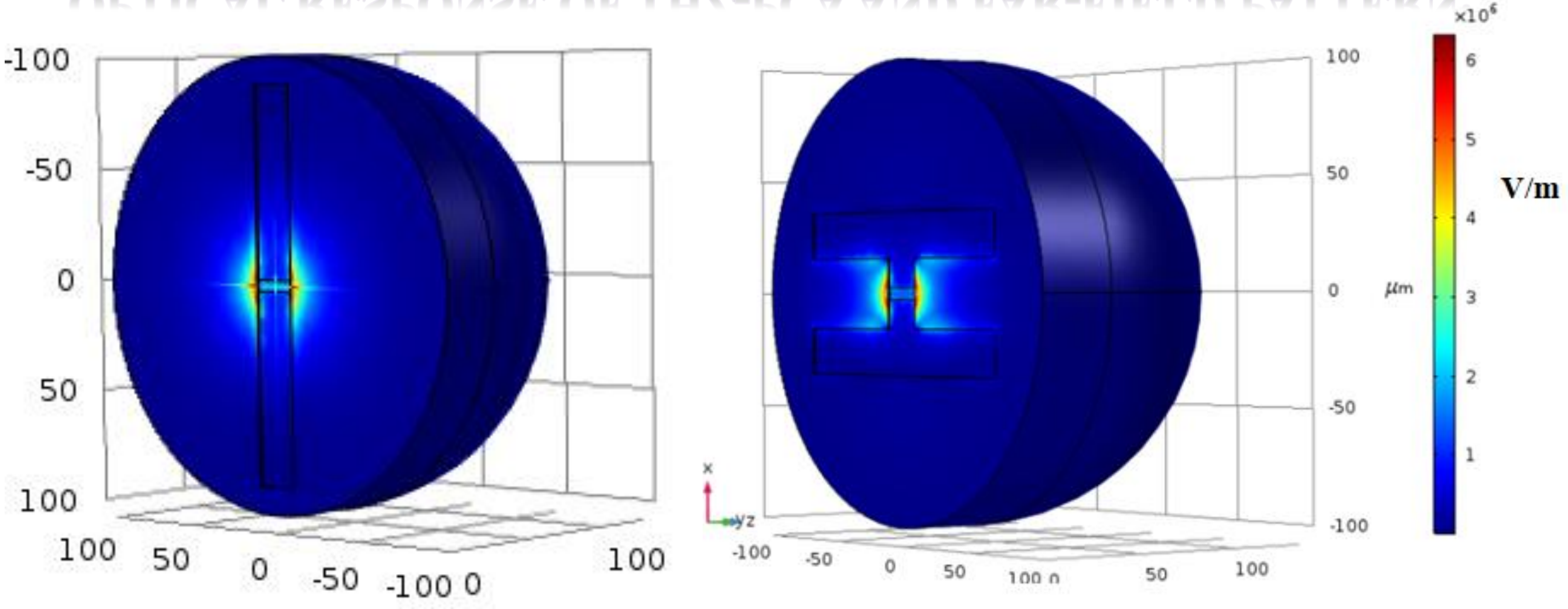
THz-PCA Parameter	**Strip dipole antenna, Fig. 2(A)**	**Hertzian dipole antenna, Fig. 2(B)**	**Hertzian dipole antenna, Fig. 2(C)**
$r_{antenna}(\mu m)$	75.76	93.46	100, 37.5b/w strip
$gap_{size}(\mu m)$	19.74	20, monotonic increase with r	20, monotonic increase
$l_{antenna}(\mu m)$	5	6, monotonic increase with g	3.75
Directivity(dB)	2.9619	3.0019	2.8052

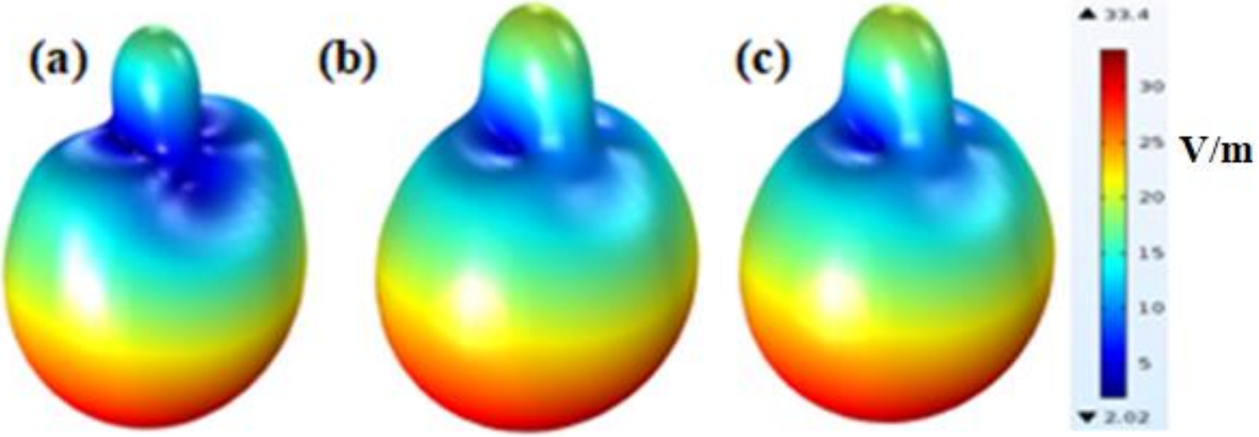
Optimized Far-field pattern

Aspect ratio:



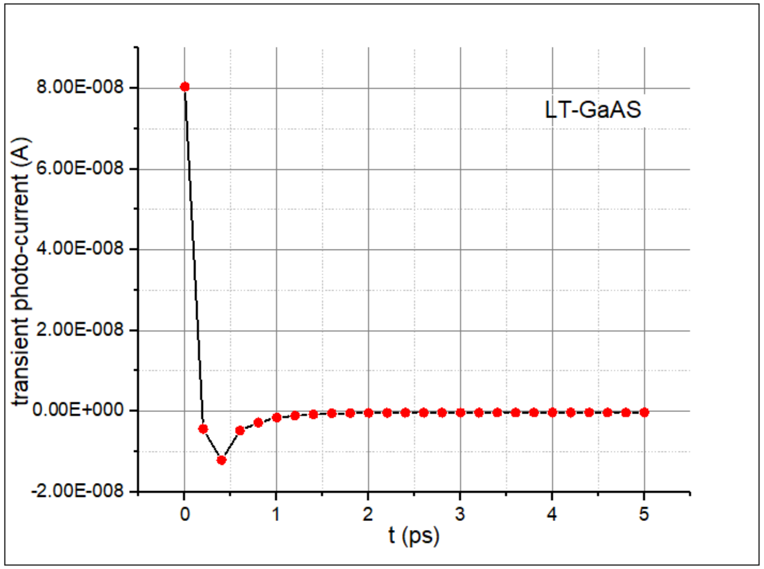
OPTICAL RESPONSE OF THZ-PCA AND FAR-FIELD PATTERN:

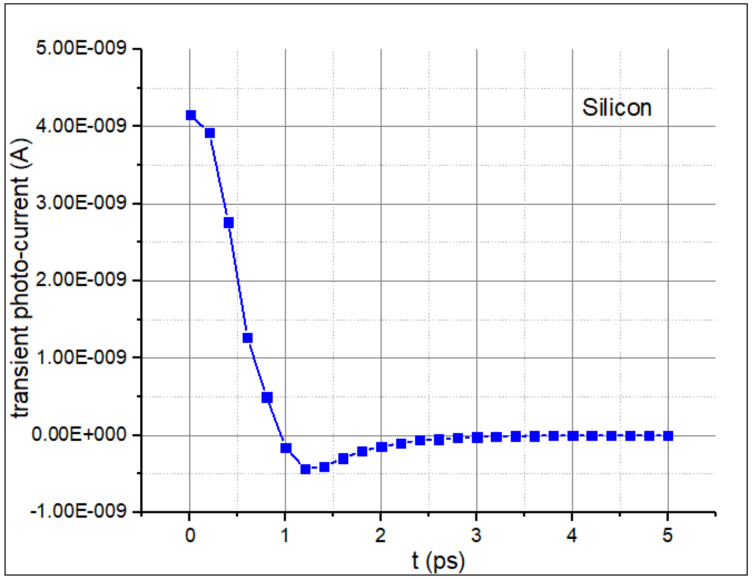


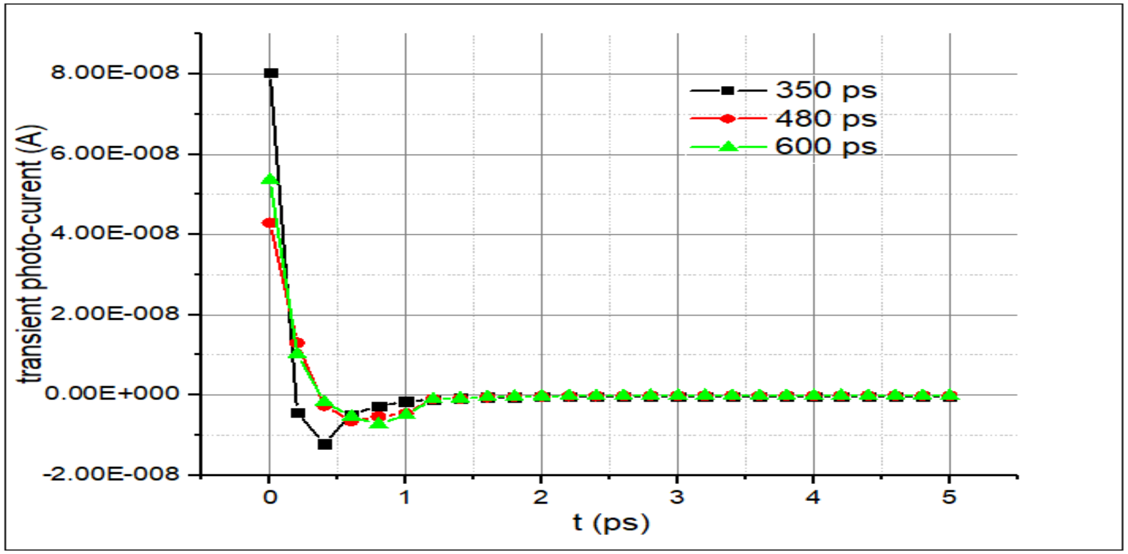


5.1002 dB **5.5222 dB** **5.7073 dB**

TRANSIENT PHOTO-CURRENT CALCULATION:







Summary:

- **The THz-PCA contribute to the compact, inexpensive, low profile future THz wireless communication system.**
- **Enhancing the output power, shrinking the size of the systems, enabling high speed frequency sweep and data acquisition.**

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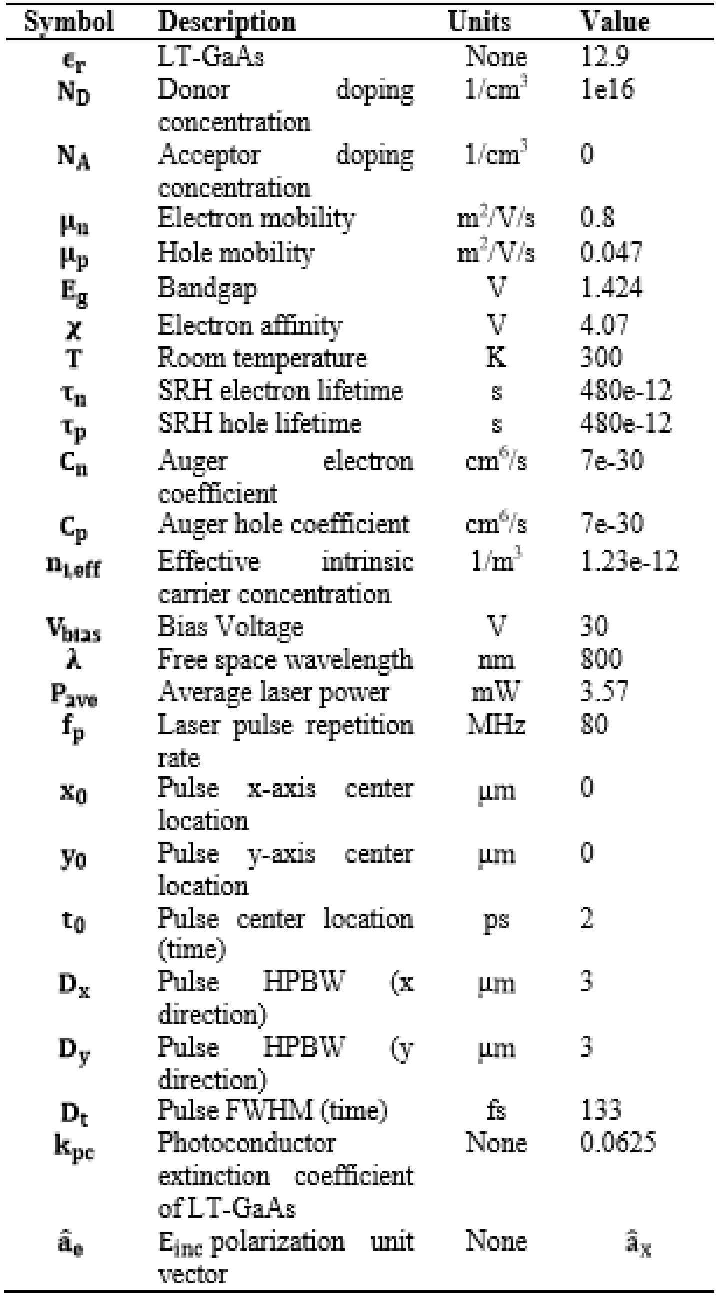
Poisson's drift-diffusion equation and Maxwell's equation

$$\epsilon_0\nabla.(\epsilon_r\nabla V) = q(n - p - N_D + N_A),$$

$$\frac{\partial n}{\partial t} = -\frac{1}{q}\nabla.\left\{-\mu_n q\nabla(V + \chi)n + \mu_n k_b T G\left(\frac{n}{N_c}\right)\nabla n\right\} - r(x,y,z) + g(x,y,z,t),$$

$$\frac{\partial p}{\partial t} = \frac{1}{q}\nabla.\left\{-\mu_p q\nabla(V + \chi + E_g)p + \mu_p k_b T G\left(\frac{p}{N_v}\right)\nabla p\right\} - r(x,y,z) + g(x,y,z,t)$$

$$\Delta \times \mu_r^{-1}(\Delta \times \vec{E}) - k_0^2\left(\epsilon_r - \frac{j\lambda\sigma}{2\pi c\epsilon_r}\right)\vec{E} = 0$$



Symbol	Description	Units	Value
ϵ_r	LT-GaAs	None	12.9
N_D	Donor doping concentration	$1/cm^3$	1e16
N_A	Acceptor doping concentration	$1/cm^3$	0
μ_n	Electron mobility	$m^2/V/s$	0.8
μ_p	Hole mobility	$m^2/V/s$	0.047
E_g	Bandgap	V	1.424
χ	Electron affinity	V	4.07
T	Room temperature	K	300
τ_n	SRH electron lifetime	s	480e-12
τ_p	SRH hole lifetime	s	480e-12
C_n	Auger electron coefficient	cm^6/s	7e-30
C_p	Auger hole coefficient	cm^6/s	7e-30
$n_{i,eff}$	Effective intrinsic carrier concentration	$1/m^3$	1.23e-12
V_{bias}	Bias Voltage	V	30
λ	Free space wavelength	nm	800
P_{ave}	Average laser power	mW	3.57
f_p	Laser pulse repetition rate	MHz	80
x_0	Pulse x-axis center location	μm	0
y_0	Pulse y-axis center location	μm	0
t_0	Pulse center location (time)	ps	2
D_x	Pulse HPBW (x direction)	μm	3
D_y	Pulse HPBW (y direction)	μm	3
D_t	Pulse FWHM (time)	fs	133
k_{pc}	Photoconductor extinction coefficient of LT-GaAs	None	0.0625
$\hat{a}_e$	E_{inc} polarization unit vector	None	$\hat{a}_x$

$$D_{\mathrm{dB}} = 10 \cdot \log_{10}\left[\frac{D}{D_{\mathrm{reference}}}\right].$$

$$D = \frac{2}{1 - cos\frac{\theta}{2}}$$

G = 10log(εD)

Directivity

- In electromagnetics, **directivity** is a parameter of an antenna or optical system which measures the degree to which the radiation emitted is concentrated in a single direction. It measures the power density the antenna radiates in the direction of its strongest emission, versus the power density radiated by an ideal isotropic radiator (which emits uniformly in all directions) radiating the same total power.
- An antenna's directivity is a component of its gain; the other component is its (electrical) efficiency. Directivity is an important measure because many antennas and optical systems are designed to radiate electromagnetic waves in a single direction or over a narrow angle. Directivity is also defined for an antenna receiving electromagnetic waves, and its directivity when receiving is equal to its directivity when transmitting.
- The directivity of an actual antenna can vary from 1.76 dBi for a short dipole, to as much as 50 dBi for a large dish antenna.