COMSOL CONFERENCE
BANGALORE 2013

Enhancement in Terahertz Emission using AuGe Nanopatterns

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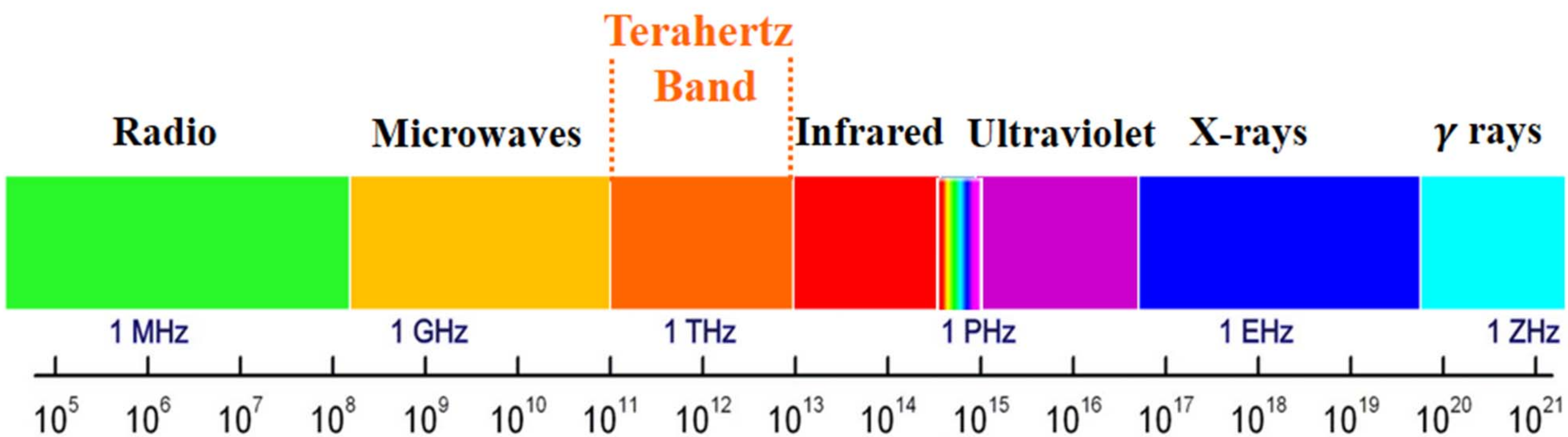
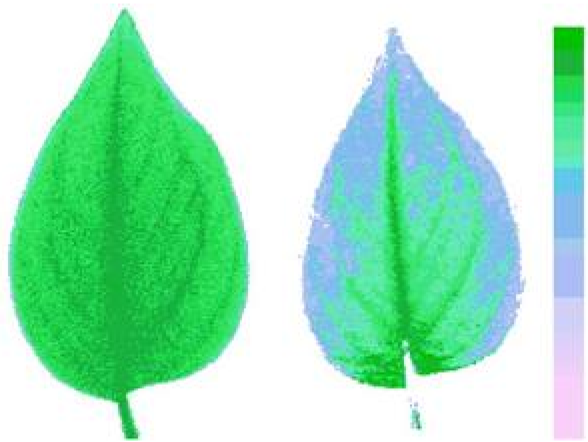
Tera… what?

- Terahertz (THz) radiation occupies the electromagnetic spectrum between optical (10^{15} Hz) and infrared (10^{13} Hz) frequencies and microwave frequencies (10^{11} Hz) i.e. wavelength ranges from 0.3mm to 3mm



Applications of THz technology are :

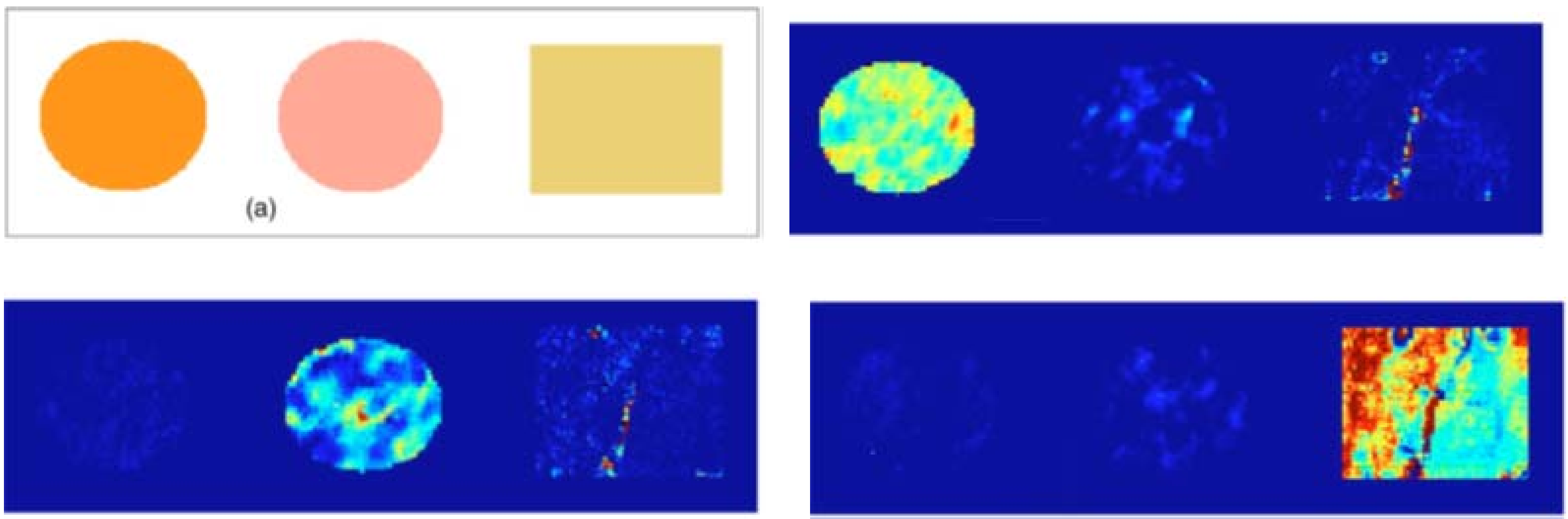
Non-invasive imaging



Water content in a leaf before and after 48 hours.

B. B. Hu and M. C. Nuss "Imaging with terahertz waves", OPTICS LETTERS / Vol. 20, No. 16 / August 15, 1995

Imaging of explosives



False-colour terahertz chemical maps showing the spatial distributions of lactose scd, sucrose sdd, and RDX.

Y. C. Shen et. al. “Detection and identification of explosives using terahertz pulsed spectroscopic imaging, APPLIED PHYSICS LETTERS 86, 241116 s2005d

Airport Security

T-Ray imaging at airport security centers to reveal concealed weapon

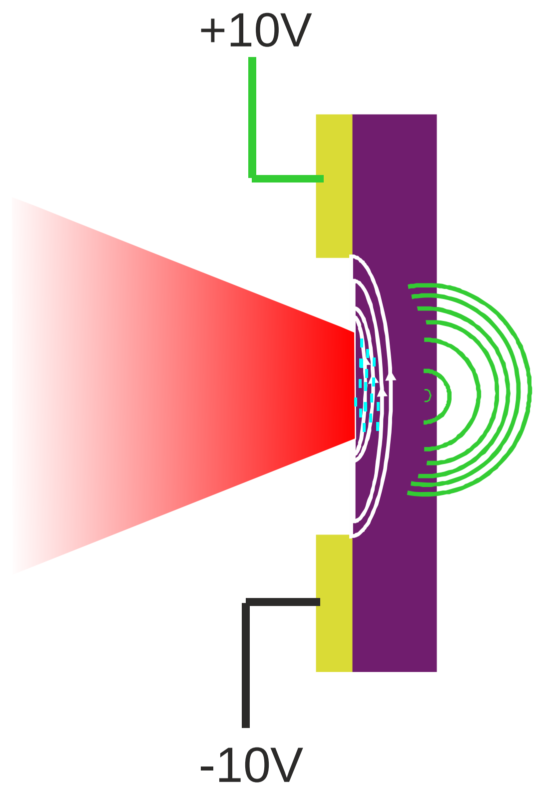
Spiegel Online, Splitternackt auf dem Monitor

THz Sources

Methods of generating THz radiation

- Photo-conductive Antenna
  - Excitation of photo-carriers by optical wavelengths
  - Acceleration of the photo-carriers to generate terahertz radiation
- Difference frequency generation
  - Mixing of two high frequencies
  - Difference between the mixing frequencies should lie in the THz range

THz PCA

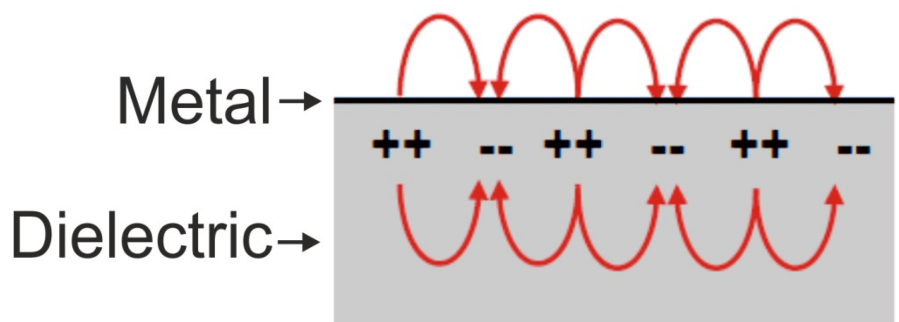


Nano-plasmonics

- Nano-plasmonics deals with the light-matter interaction at very small geometries

Surface Plasmons Polaritons

- Plasmons are collective electron oscillations



- SPPs are a result of the coupling of the incident light’s electromagnetic field to the oscillations of the metal’s electron plasma.

Surface Plasmons Polaritons

- They follow the following dispersion relation

$$\kappa_{SPP} = \kappa_0 \sqrt{\frac{\varepsilon_a \varepsilon_b}{\varepsilon_a + \varepsilon_b}}$$

- Where κ_{spp} is the momentum of the SPP and κ_o is the free space vector

$$\left(\kappa_0 = \left(\frac{\omega}{c} \right) \right)$$

Surface Plasmons Polaritons

- By observing the left hand side of the equation we can see that for a air-dielectric interface, κ_{spp} is greater than the left hand side of the equation
- This means we should compensate for the extra momentum in order to excite SPPs from air.
- The metallic grating provides an extra momentum along the direction of the grating

Surface Plasmons Polaritons

- Hence, to excite SPP, the condition to be satisfied should be

$$\kappa_{SPP} = \kappa_0 \sqrt{\frac{\varepsilon_a \varepsilon_b}{\varepsilon_a + \varepsilon_b}} = \kappa_0 \sin\theta + \vec{G}$$

where

$\vec{G} = \frac{2\pi}{\Lambda}$, Λ being the grating period

Surface Plasmons Polaritons

- But for a normal incidence θ is zero and hence the equation becomes

$$\kappa_0 \sqrt{\frac{\varepsilon_a \varepsilon_b}{\varepsilon_a + \varepsilon_b}} = \frac{2\pi}{\Lambda}$$

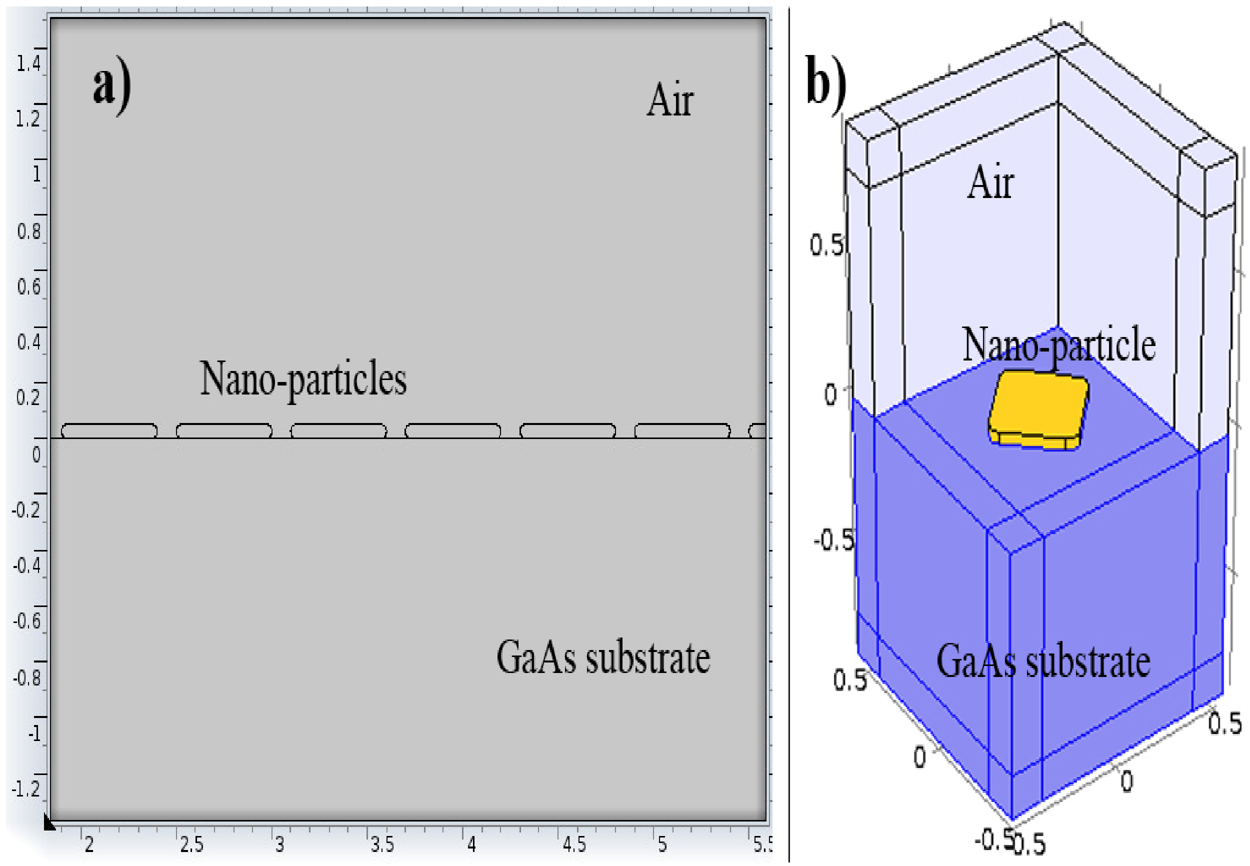
- Hence from the equation we can calculate the grating period needed to excite SPP
- The excitation of the SPP, local electric field is enhanced which in turn produces larger number of photo-carriers

Surface Plasmons Polaritons

- The only thing remaining to do is to determine the thickness of the nano-patterns
- This is done by using COMSOL's parametric sweep of the height of the nano-patterns which are separated by the period as calculated previously

COMSOL SIMULATION

2D and 3D simulation



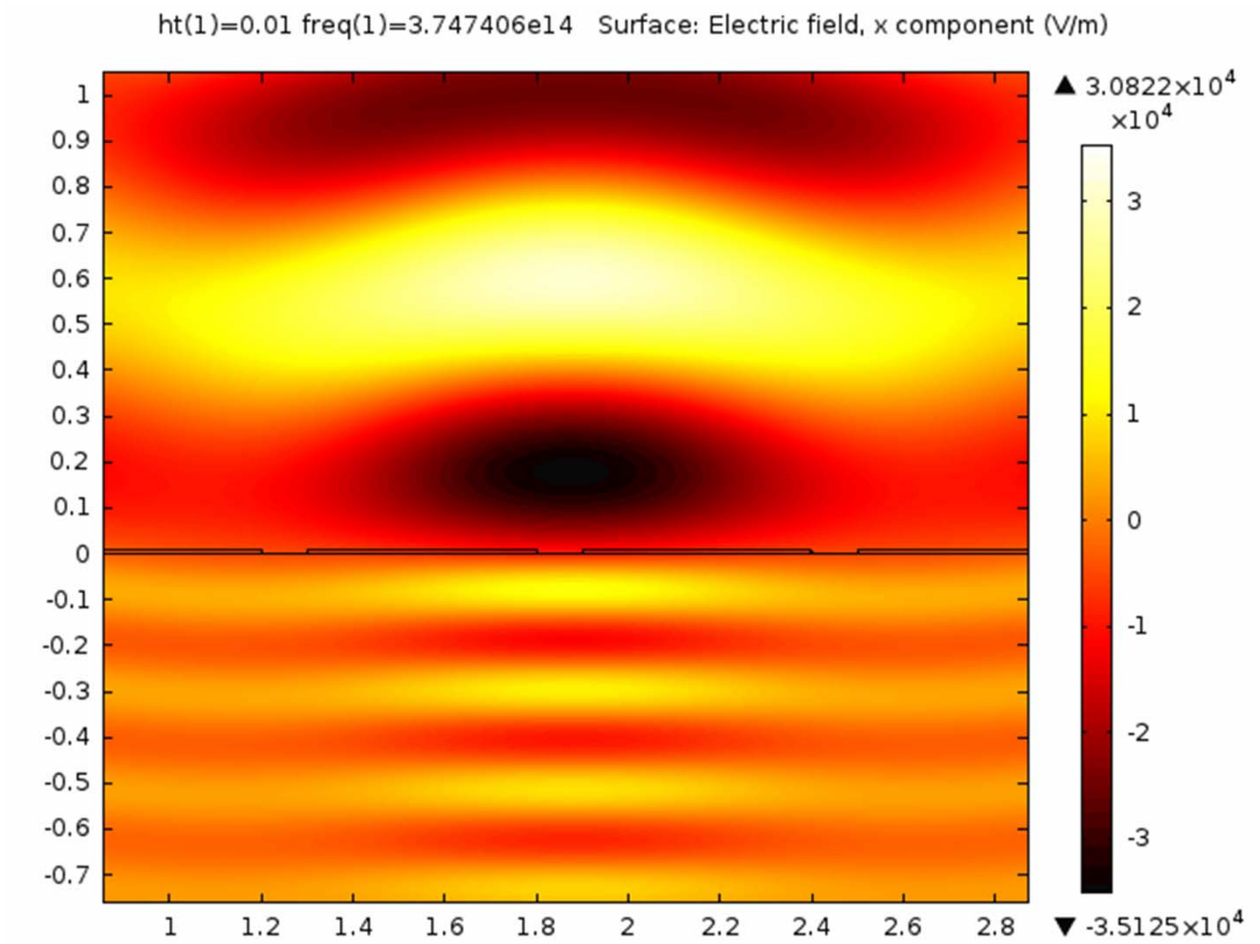
COMSOL SIMULATION

- A plane wave is made incident on the GaAs substrate with the AuGe nano-patterns
- “Electromagnetic Waves, Frequency Domain” interface in the Wave Optics module was used
- Appropriate values of ε_r (relative permittivity), μ_r (relative permeability) and σ (electrical conductivity) are given according to the materials

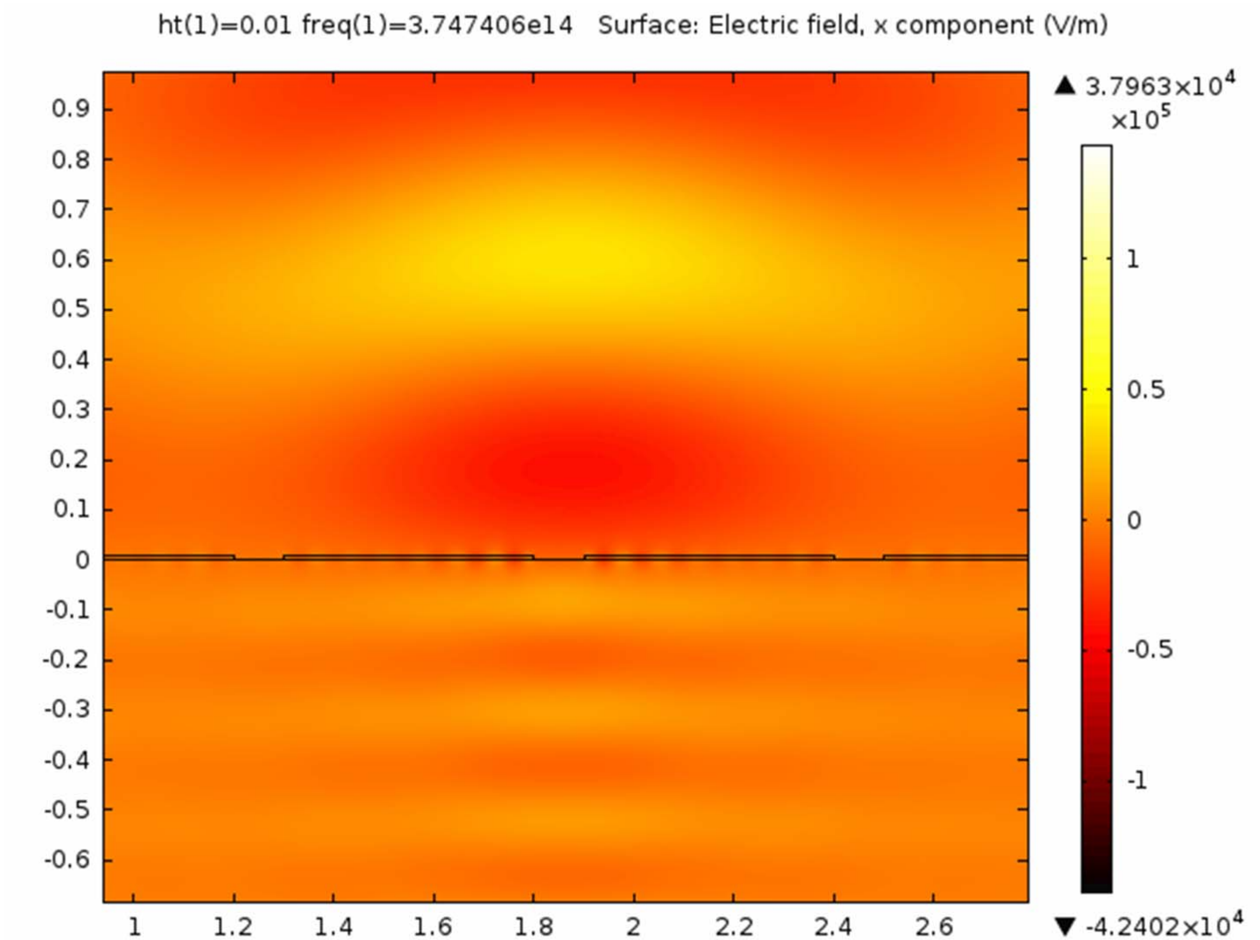
COMSOL SIMULATION

- Parametric Sweep of the height of the nano-patterns is done to find out the optimal height where the local electric field will be maximum

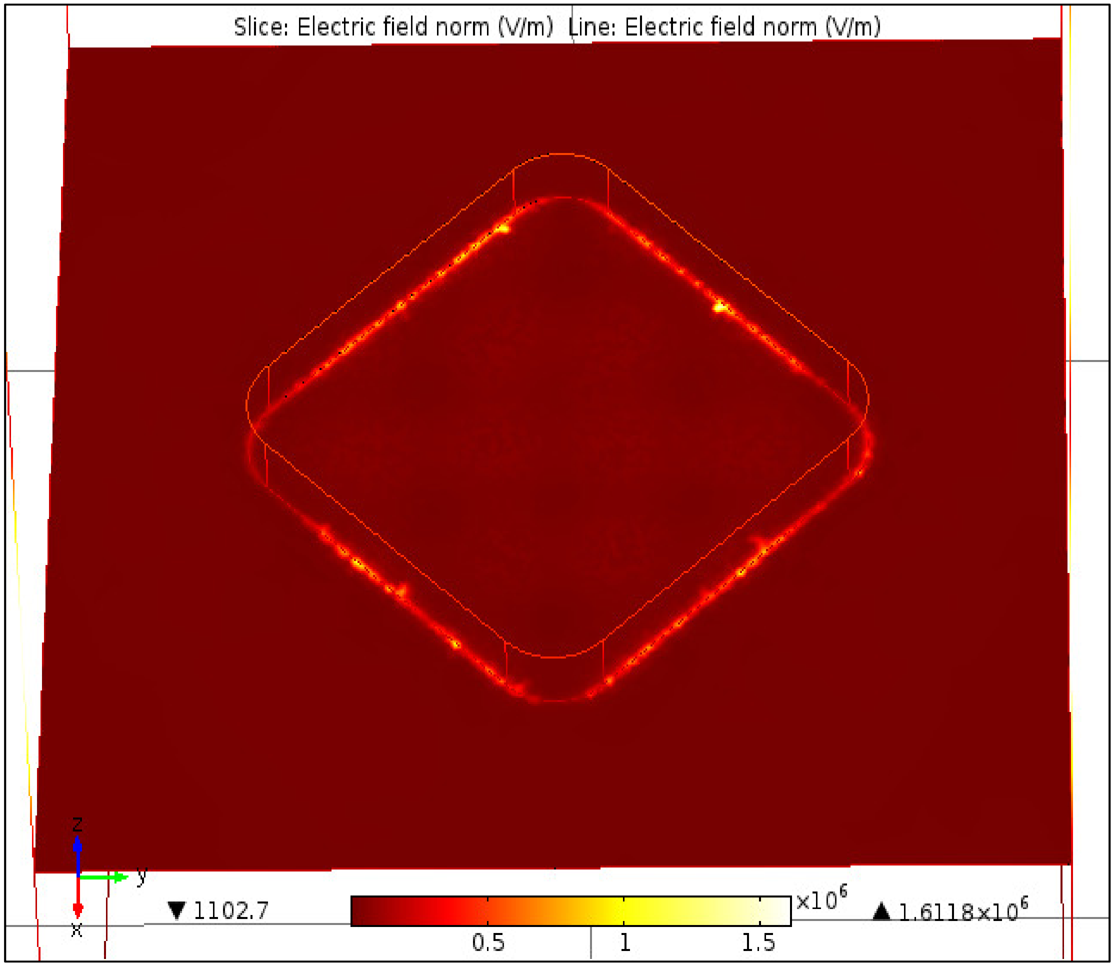
COMSOL Simulation without the effect of AuGe nano-patterns



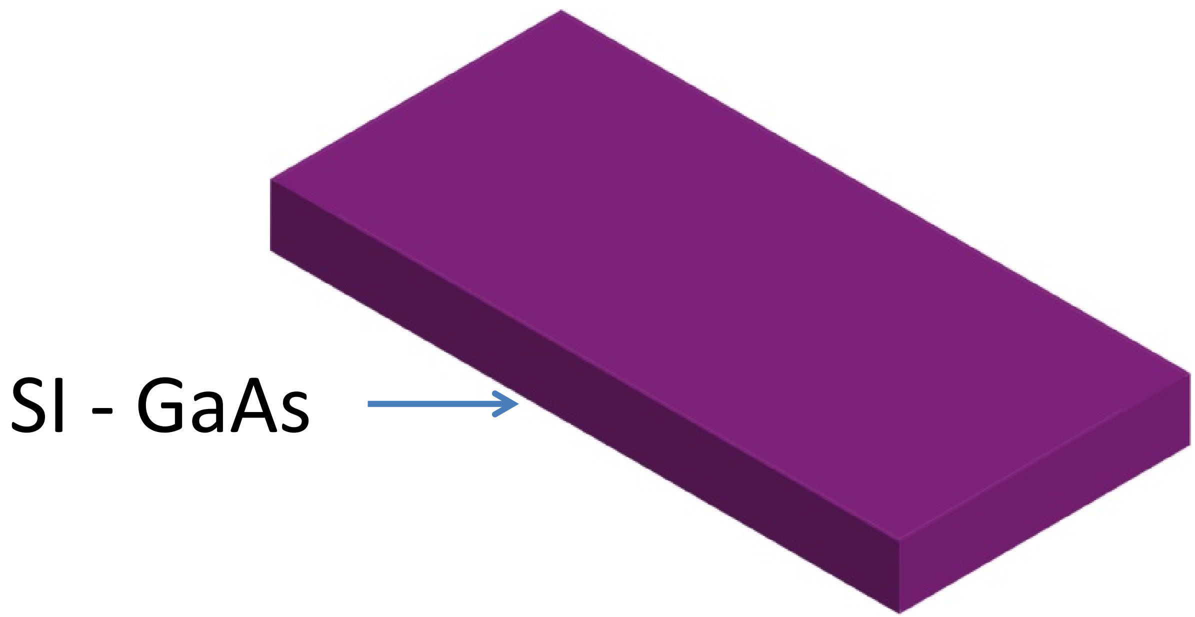
COMSOL Simulation with the effect of AuGe nano-patterns



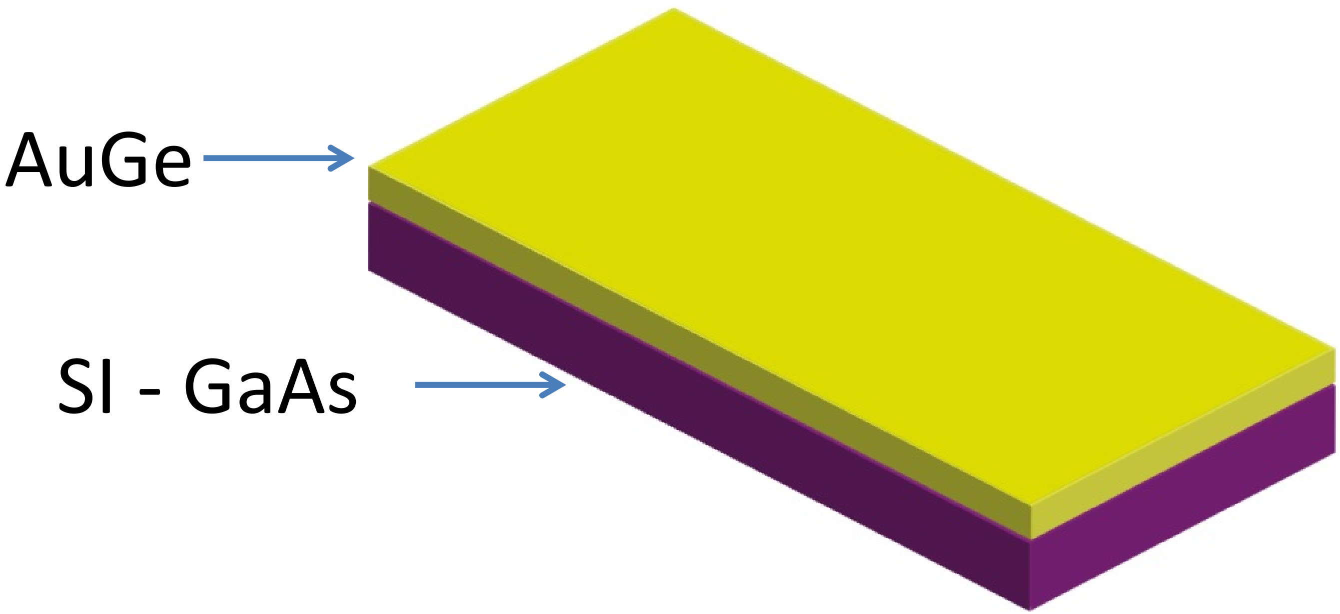
COMSOL SIMULATION



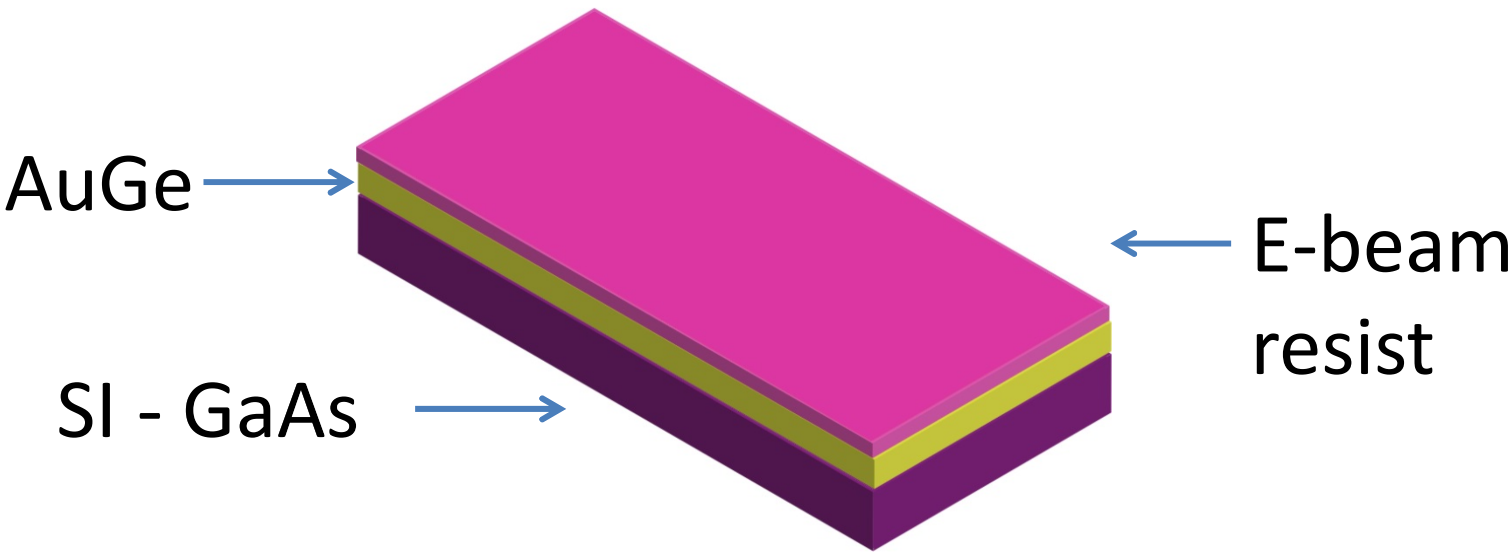
Fabrication



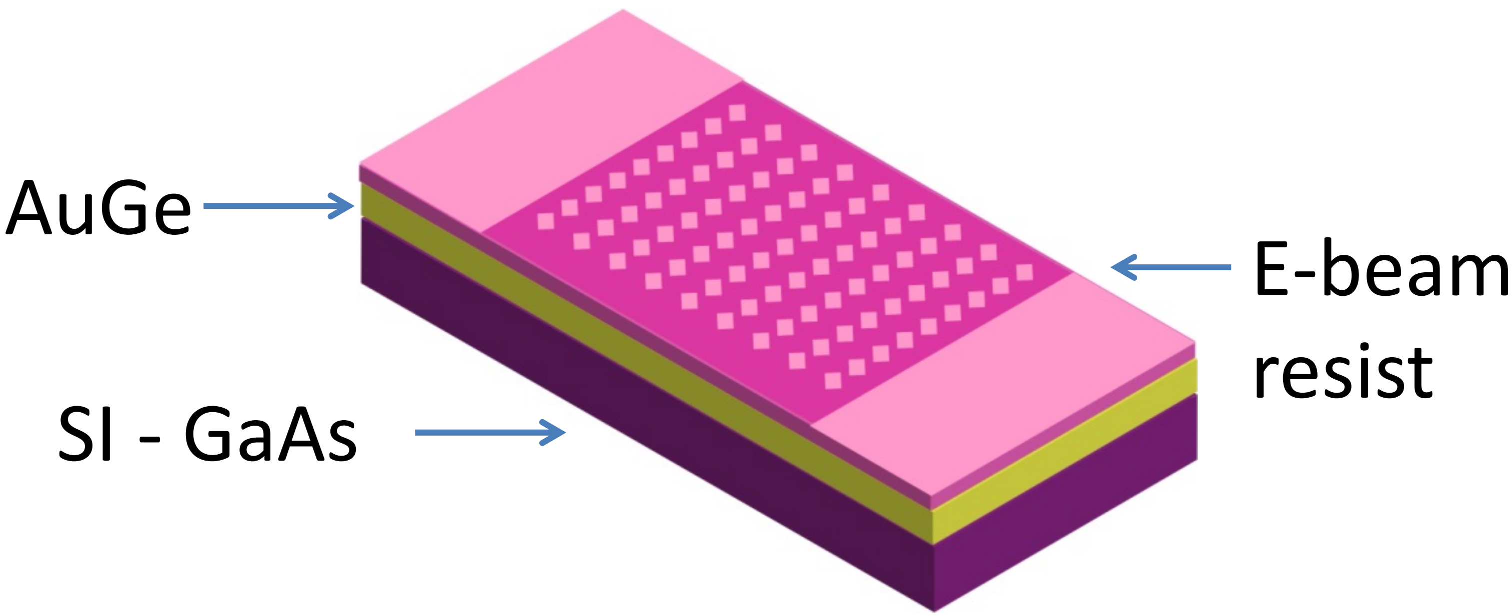
Sputter deposition of 40nm layer of AuGe on GaAs substrate



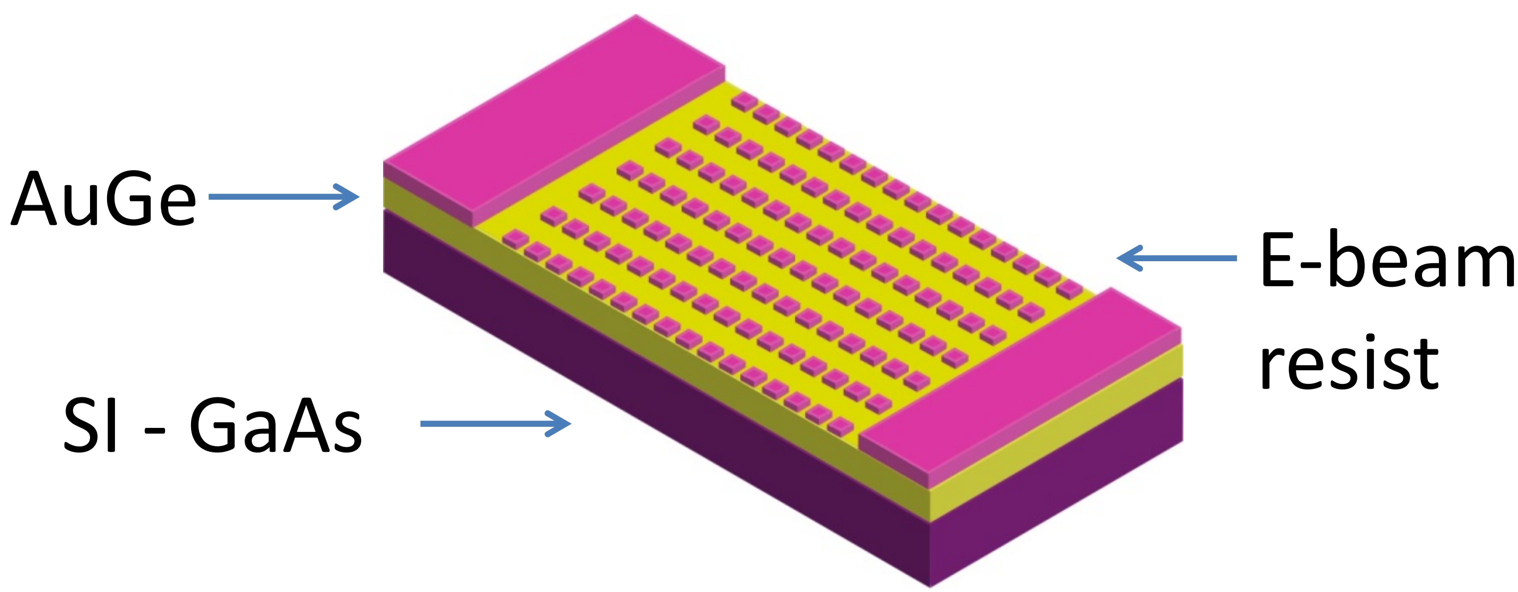
Spin coating the E-beam resist onto the sputtered waffer



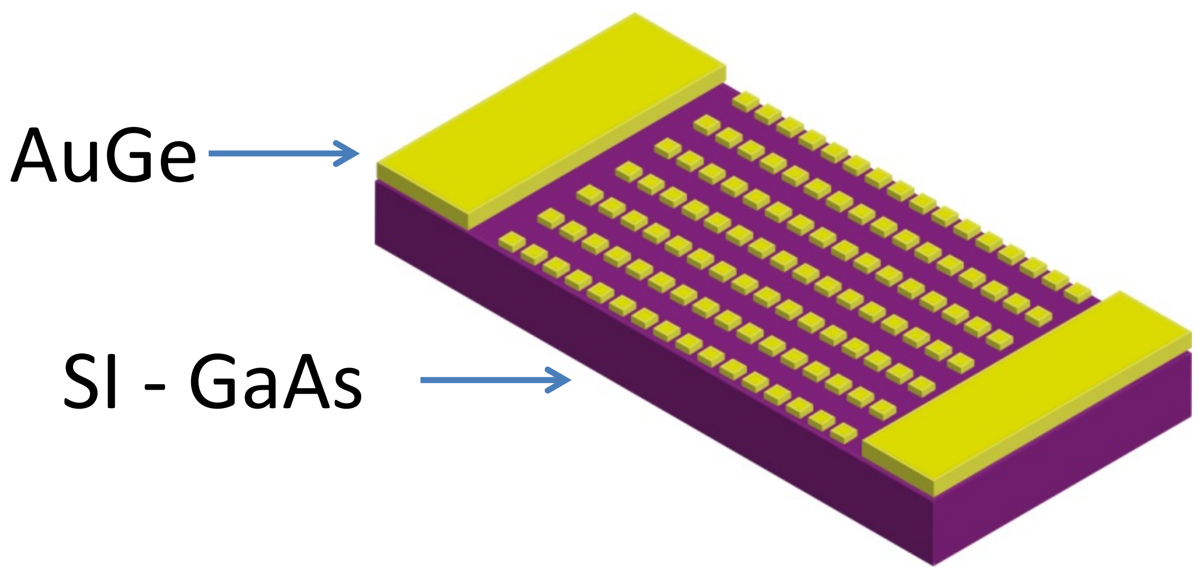
Writing THz antenna pattern with E-beam lithography



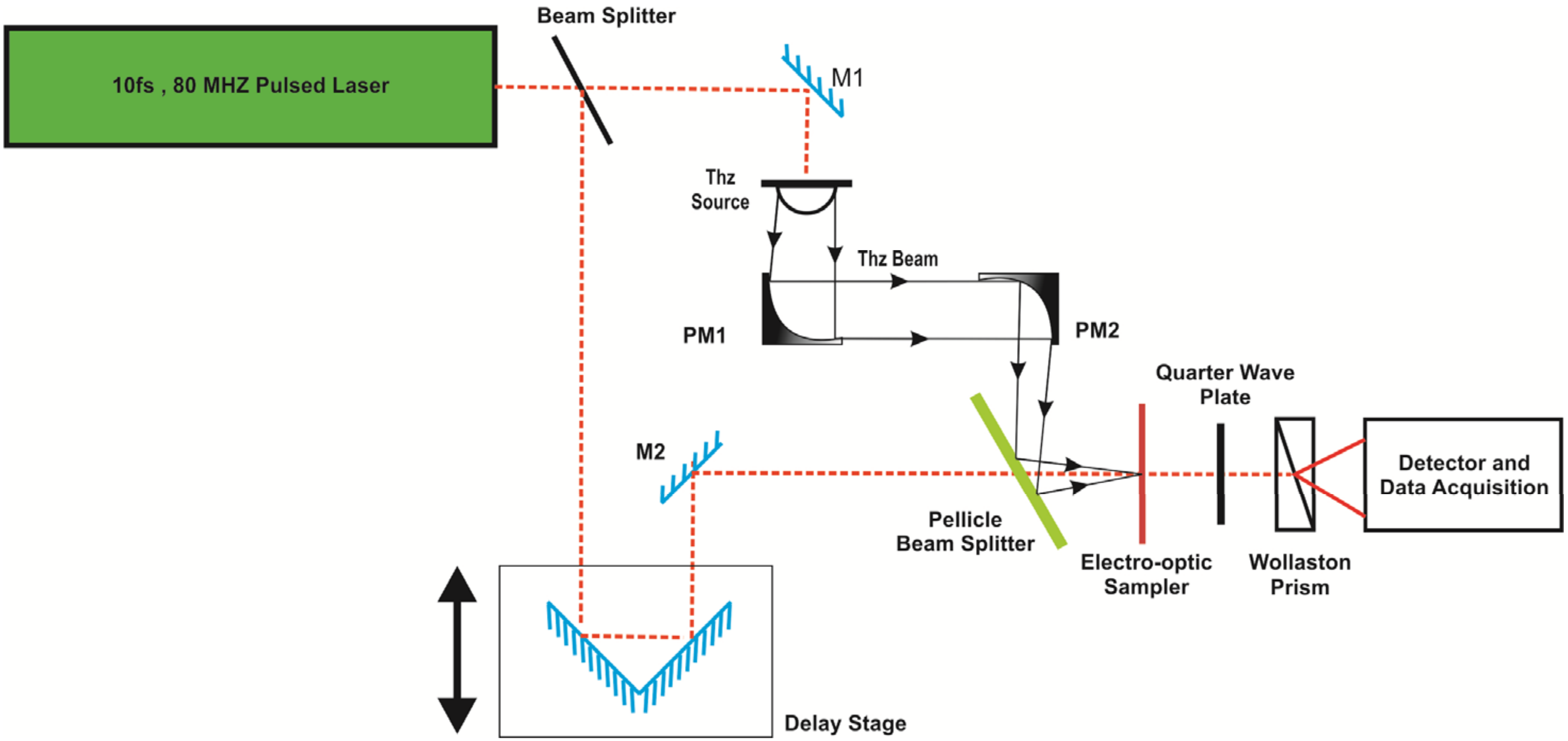
Developing the exposed pattern with developer solution



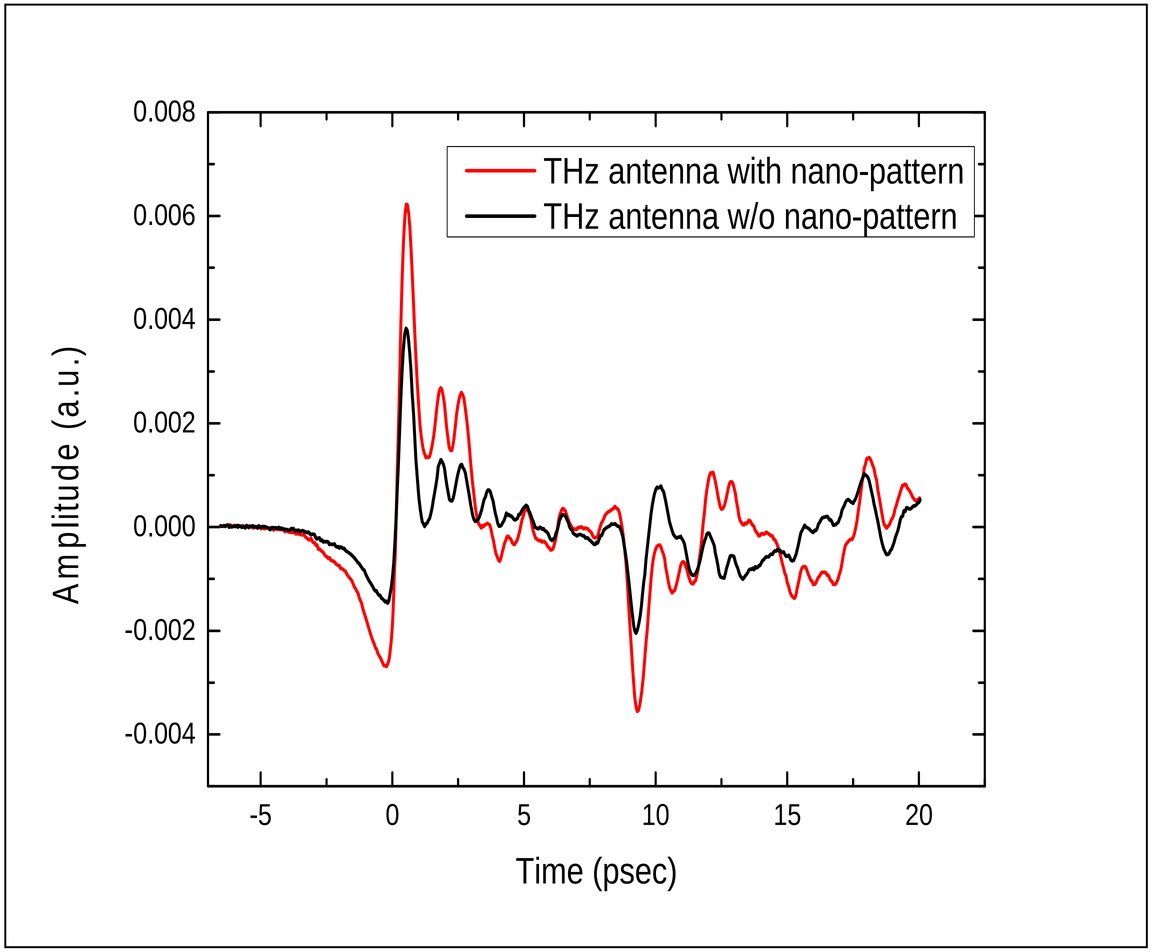
Etching out the rest of AuGe to extract the pattern



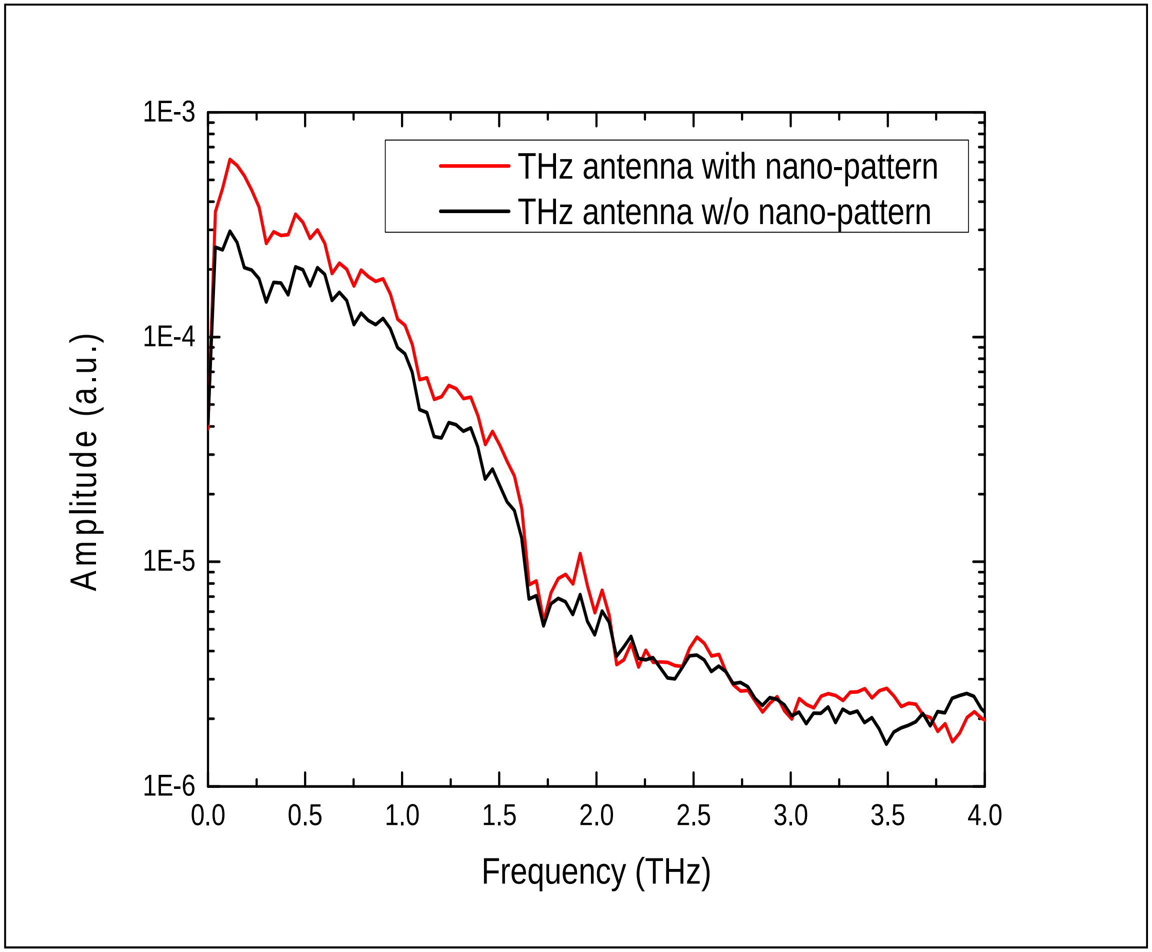
Experimental Setup



Experimental Data



Experimental Data



THANK YOU

- THz radiations can excite vibrational modes in a material