# Active Control of Polarization and Plasmon Induced Transparency in THz Metamaterial

Ruchi Bhati*, Anil K. Malik
Department of Physics, Ch. Charan Singh University Meerut, Uttar Pradesh-250004, India
***Email id -** ruchibhati2612@gmail.com

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Dynamical manipulation of plasmon-induced transparency (PIT) in metamaterials promises tremendous potential applications including optical sensors, modulators, slow light devices and optical switching [1-4]. Active control of terahertz wave is critical for the development of terahertz devices. Due to the extraordinary properties, two dimensional materials offer more choices for opto-electrical devices with the maturity of their preparation technology. We report a simple structure of metamaterial unit cell to realize dynamically controllable PIT effect and polarization, simply by changing the horizontal/ vertical displacement between the resonators and polarization direction of incident light. We investigate its optical properties in terahertz range. We investigate the phenomenon of the plasmon-induced transparency (PIT) effect in the transmission spectra, resulting from near-field coupling of two resonators. Simulation results confirm PIT dependency on the dimensions of unit cell and distance between resonators. This work provides a simple approach for designing a compact and tunable PIT devices.

**References: -**

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## THz Metamaterials

- THz region is located at the interface of electronics and photonics. This gap is caused by weak/nonexistent materials response at THz frequencies.
- Results in a lack of sources, detectors, sensors, modulators, polarizers, filters, etc. in the THz regime.
- Metamaterials (MMs) may help to get over this dilemma because MMs are artificially engineered materials with properties derived from their sub-wavelength structures, rather than the materials from they are made of. e.g., simultaneously $\varepsilon<0$ and $\mu<0 \rightarrow n<0$.

## Plasmon induced transparency

- Plasmon-induced transparency (PIT) is analogous effect to the classical quantum electromagnetically induced transparency (EIT) phenomenon. It results from the destructive interference between two resonances, which are coupled to the radiation field on one chip
- PIT is an effective strategy to control the transmission properties of the incident THz wave with designed metasurface structures by adjusting the geometric parameters and varying the distance between two resonators.
- This phenomenon has potential applications for designing nanosensors with high performance due to the sharp resonance of the light near the appeared transparency window

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## Geometry of the Metamaterial unit cell

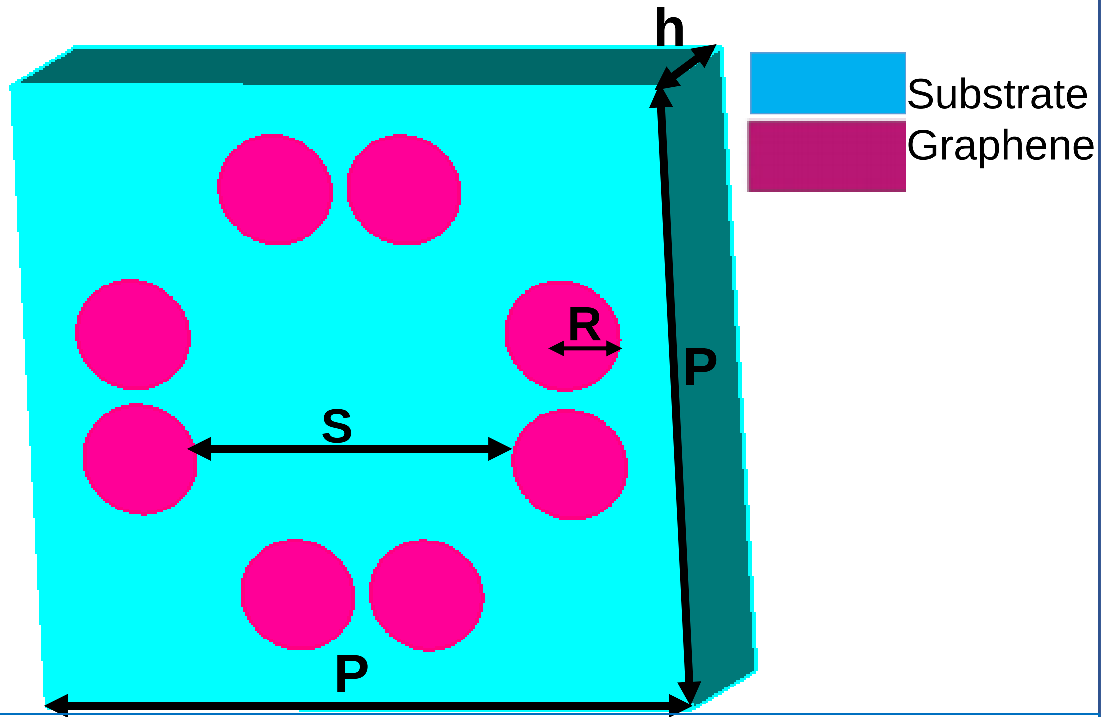


**Fig.1** Schematic diagram of metamaterial unit cell geometry. The geometrical parameters of unit cell are :-P=30µm, S=14.5µm, R=2.6µm, h= 10µm and separation between two resonators are 0.5µm

## CST results for amplitude transmission

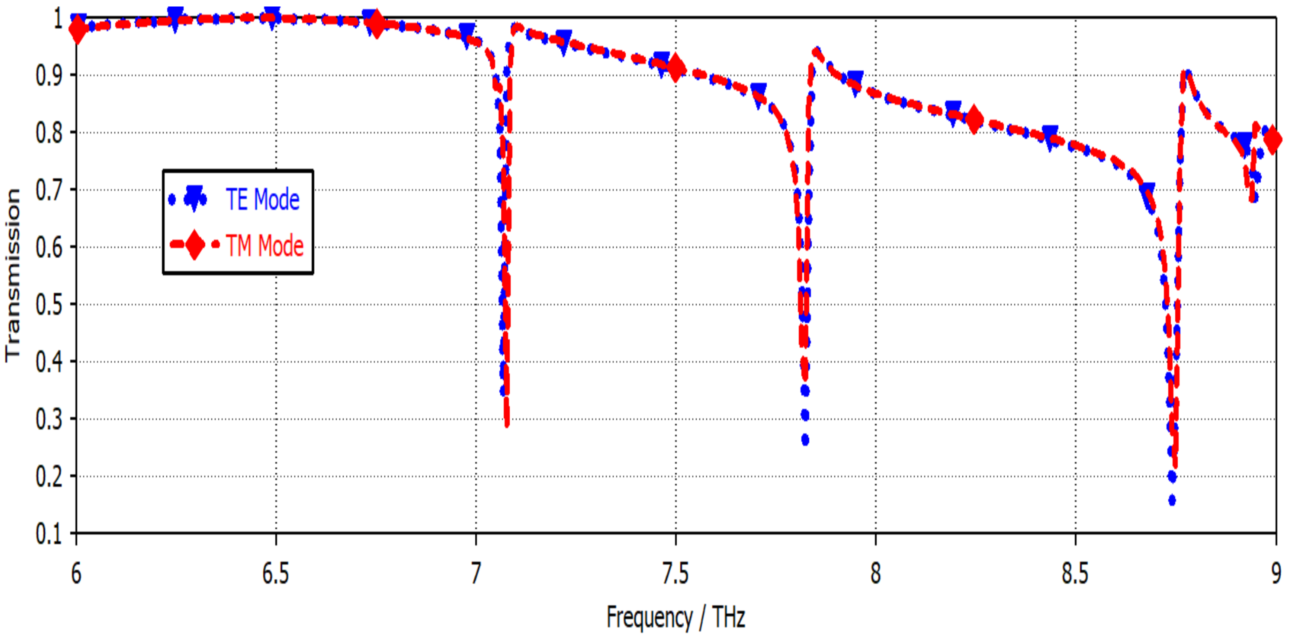


**Fig.2** The normalized transmission curves of transverse electric(TE) and magnetic(TM) mode(Blue curve shows the TE mode while Red curve shows the TM mode).

It depicts that our proposed metamaterial unit cell is insensitive for the direction of polarization.

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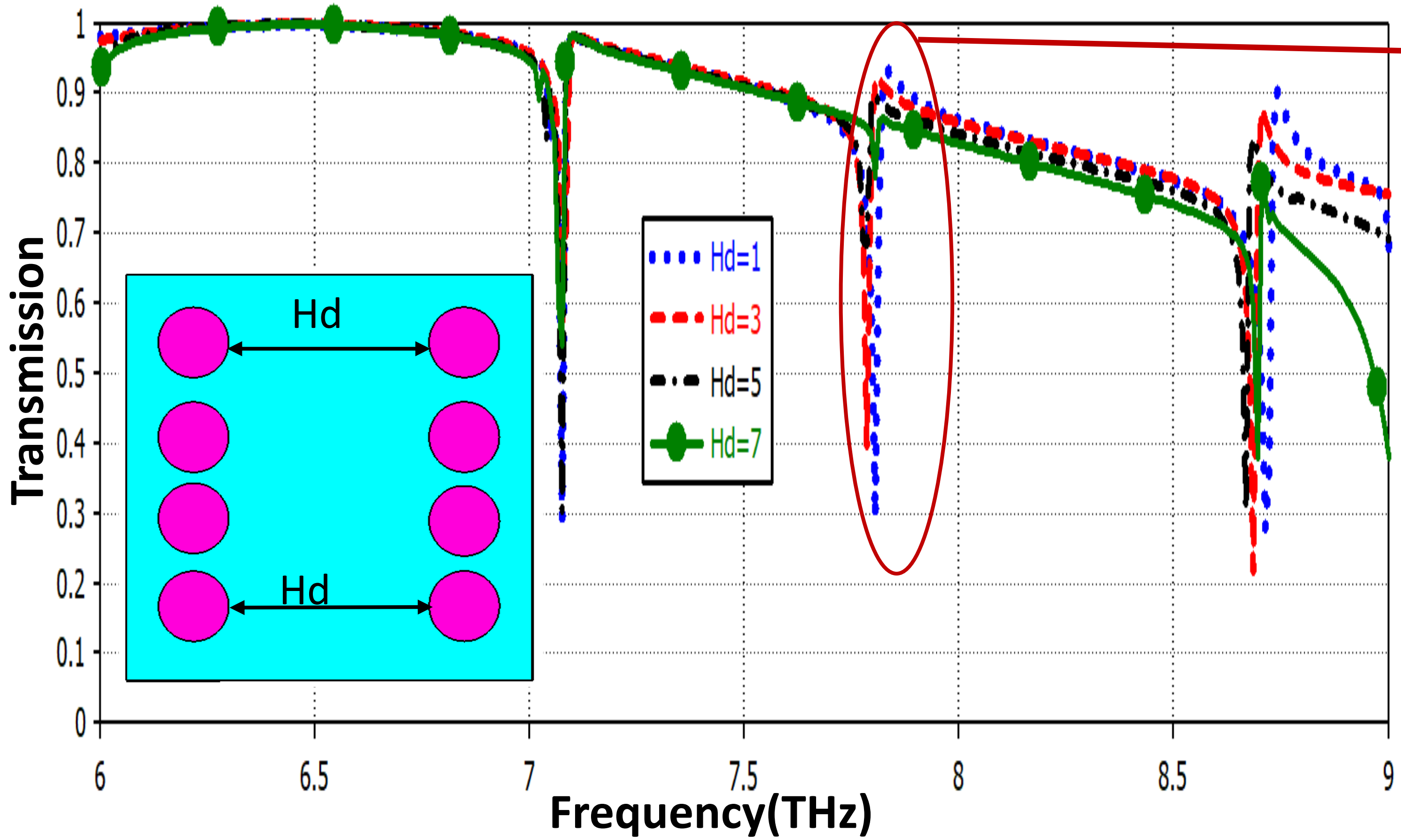
## Transmission spectra for different horizontal displacement



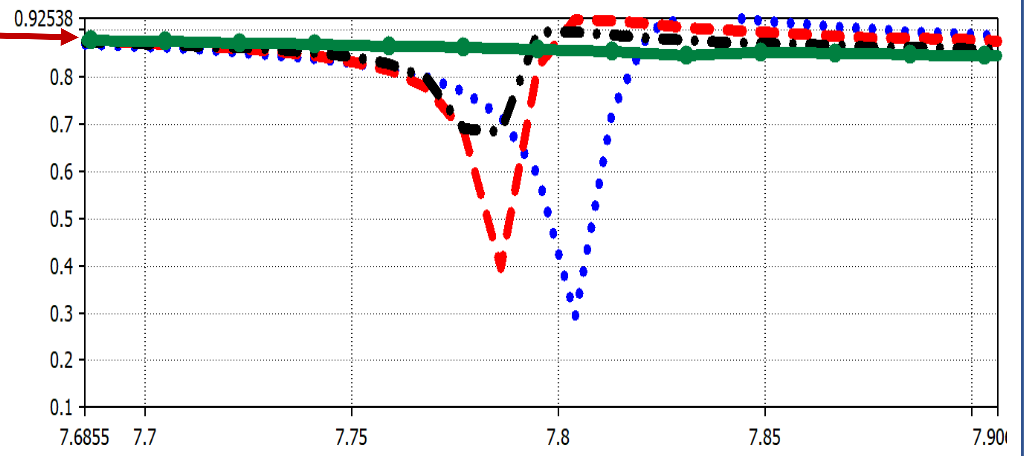




**Fig. 3**. Transmission versus Frequency spectra for different horizontal displacement(Hd) between upper and lower resonators.

This curve represents that as Hd is increases 2nd resonant frequency decreases and at Hd=7µm, it disappears completely and we get only a single transparency window.

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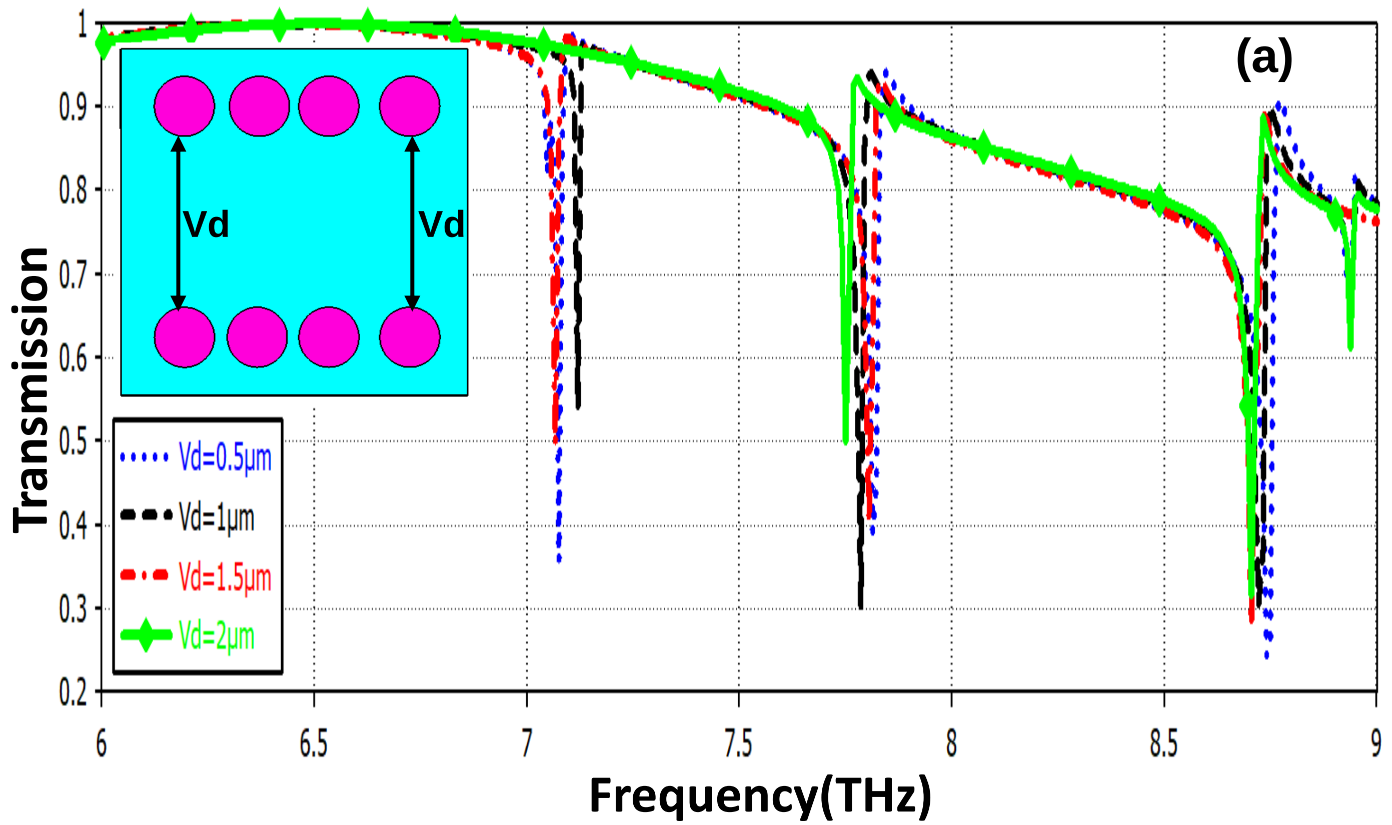
## Transmission spectra for different vertical displacement



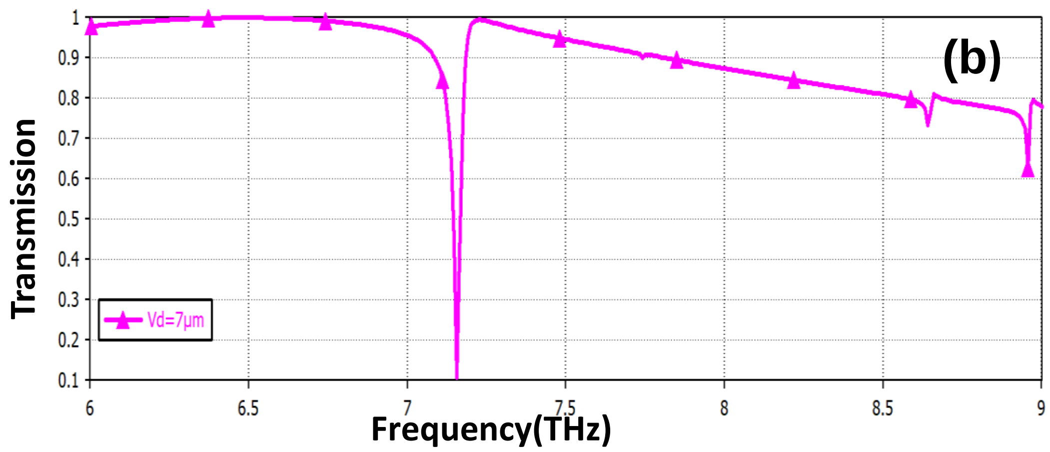




**Fig. 4** Transmission amplitude curve for different vertical displacement between left and right resonators.

Fig.4(a) curve represents that as Vd increases 1st resonant frequency decreases and at Vd=2μm, it disappears completely and we get only a single transparency window. Fig. 4(b) shows that at V=7μm both the transparency window disappears and we get only single resonant frequency.

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In this work, we have numerically investigated the tunable plasmonic induced transparency based on graphene patterns in terahertz regime, including the effect of structural parameters and direction of polarization. Conclusions of this work are as follows :-

- Our proposed MM unit cell is insensitive to the direction of polarization.
- By changing the horizontal displacement between upper and lower side resonators, we can actively control the first transparency window.
- Second transparency window can be tuned by varying the vertical displacement between left and right side resonators of MM unit cell.
- The independent modulation of the PIT transparency windows will provide us the flexibility to choose the desired frequency for device designing and construction.