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Reconfigurable MEMS metamaterial based active THz photonics

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Metamaterials are well-known for their tunable and unnatural properties that are not usually accessible in natural materials. Recently, there is a large growing interest in the actively tunable metamaterials, where their structural/optical can be actively tuned using an external means, such as optical pulse, thermal and electrical controls. Among them the microelectromechanical systems (MEMS) based metamaterials have given useful features of multiple controls in engineering their structural geometry in all the three-spatial directions of the sample at the THz frequencies. This allows to probe and engineer unique and intriguing near-field coupling phenomena in metamaterials, thereby obtaining the electro-optical properties on demand.

In one of our recent works [1], we demonstrated a new regime of excitation and tuning of Fano resonance in an out-off plane reconfigurable MEMS metamaterial using two input voltage controls at THz frequencies. The excitation of Fano resonance exhibits an anisotropic coupling behavior, which results in multiple-input-output states resembling the hysteretic type of response in the electro-optical properties of metamaterial. The observed MIO states in the electro-optical response of the metamaterial display digital functionalities such as XOR, XNOR, NAND logical operations at THz frequencies. We further show that the XOR logical function of metamaterial could exhibit potential applications in the secured cryptographic communication networks and for programable metamaterials at THz frequencies.

In the second work [2], we demonstrated an active control of invisibility cloak effects in a composite metamaterial consisting of a split ring resonator (SRR) and MEMS actuated closed ring resonator (CRR) structures. We show that using the voltage-controlled actuation of the MEMS CRR structure, the SRR structure is switched between its visible and invisible states. The results show that by changing the out-off plane angle of the MEMS structure using the voltage control, the effective material parameters such as permittivity and permeability of the medium can be dynamically tuned, thereby actively switching the invisibility effects in the medium. The proposed design could enable real time applications such as switches, active phase modulators and resonance cloaking devices at terahertz frequencies.

1. Manukumara Manjappa, Prakash Pitchappa, Navab Singh, Nan Wang, Nikolay I Zheludev, Chengkuo Lee, Ranjan Singh, “Reconfigurable MEMS Fano metasurfaces with multiple-input-output states for logic operations at terahertz frequencies” *Nature Communications*, **9**, 4056 (2018). doi: 10.1038/s41467-018-06360-5

2. Manukumara Manjappa, Prakash Pitchappa, Nan Wang, Chengkuo Lee, Ranjan Singh, “Active Control of Resonant Cloaking in a Terahertz MEMS Metamaterial”, *Advanced Optical Materials*, **6**, 1800141 (2018). doi: 10.1002/adom.201800141.