Excitation of Fano resonances in symmetric terahertz metasurface cavity

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Fano resonance is a very rich and interesting phenomena in physics which have attracted intense attention due to their sharp asymmetric spectral feature and low radiative loss channel [1, 2]. Fano resonance has been excited in metamaterials to realize highly compact devices for reducing radiation loss, solar energy harvesting, strong near-field confinement, highly sensitive sensors and tunable antenna design etc. [1 - 4]. Although, most of the configurations require structural asymmetry to excite Fano resonance having low sub-wavelength surface area to interact and confine electromagnetic energy to be employed in above mentioned applications [5 - 7]. In this paper, we have demonstrated the unique ability to excite Fano resonances in a geometrically symmetric terahertz metasurfaces [5, 7] as well as confine electromagnetic energy in ultra-thin, deep sub-wavelength cavity. The proposed structure consists of a vertically stacked symmetric resonator arrays separated by an ultrathin polyamide spacer (th_{cavity}) (Fig. 1(a)) ranging from 0.4 to 1.25 μm. Detailed geometric dimensions are given in the caption of Fig. 1. When the resonators above and below polyamide are excited with electromagnetic field with polarization along the length of the resonator, individual resonances are excited, which are detuned to each other due to different ambiences they experience. Destructive interference between them causes sharp, asymmetric Fano resonance. Fig. 1(b) shows transmission response of the device with different polyamide thickness. Such metastructures can strongly support highly localized, intense electromagnetic fields confined inside deep-subwavelength cavity regime ($th_{cavity} < \lambda/_{100}$) where stronger confinement is observed at Fano resonance compared to dipole resonance (in Fig. 1(c)). Such exotic features of perfectly symmetric Fano resonators provide a novel possibility for strong light–matter coupling resulting in realization of ultrasensitive sensors, energy efficient ultrafast terahertz modulators; which will be presented in the conference.

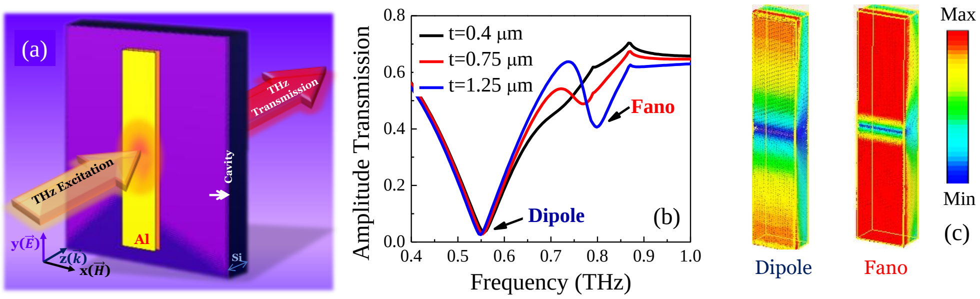

Fig. 1: (a) Schematic illustration of proposed metamaterial structure. Dimensions of the unit cell are as follows: Periodicity (P_x, P_y): (100, 110) μm, resonator length L: 100 μm, resonator width w: 20 μm. thickness of cavity/ spacer (th_{cavity}) = (0.4 – 1.25) μm. (b) Amplitude transmission spectra corresponding to different th_{cavity} filled with polyimide. (c) Electric field distribution in the unit cell at dipole (left) and Fano dip (right).

References:

[1] M. F. Limonov, M. V. Rybin, A. N. Poddubny and Y. S. Kivshar, "Fano resonances in photonics," Nat. Photonics **11**, 543–554 (2017).
[2] S. Karmakar, R. K. Varshney, and D. Roy Chowdhury, "Theoretical investigation of active modulation and enhancement of Fano resonance in THz metamaterials," OSA Continuum **2**, 531-539 (2019).
[3] B. Lukyanchuk, N. I. Zheludev, S. A. Maier, N. J. Halas, P. Nordlander, H. Giessen, and C. T. Chong, "The Fano resonance in plasmonic nanostructures and metamaterials," Nat. Materials **9**, 707–715 (2010).
[4] S. Karmakar, R. K. Varshney, D. Roy Chowdhury, and B. P. Pal, "Fano resonances in terahertz metamaterials," Asian Journal of Physics **28 (7-9)**, 663-685 (2019).
[5] S. Karmakar, S. Banerjee, D. Kumar, G. Kamble, R. K. Varshney, and D. Roy Chowdhury, "Deep-Subwavelength Coupling-Induced Fano Resonances in Symmetric Terahertz Metamaterials," Phys. Status solidi RRL **13**, 1900310 (2019).
[6] S. Karmakar, D. Kumar, R. K. Varshney, and D. Roy Chowdhury, "Lattice induced plasmon hybridization in metamaterials," Opt. Lett. **45**, 3386-3389 (2020).
[7] S. Karmakar, D. Kumar, R. K. Varshney, and D. Roy Chowdhury, "Strong terahertz matter interaction induced ultrasensitive sensing in fano cavity based stacked metamaterials," J. Phys. D, **124081.R1** (2020). https://doi.org/10.1088/1361-6463/ab94e3.