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Plasmonic split ring resonator with energy enhancement for the application of bio-sensing and energy harvesting based on the Second Harmonic Generation and Multi Fano resonance

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Abstract **— Plasmonic characteristic has been implemented for optical enhancement and the Fano resonance is noticed based on the interaction of the dark and bright mode at nano particle and for more enhancement, the second harmonic generation and multi Fano have been suggested. In this paper, we have designed a nano-antenna based on plasmonic, Fano, multi Fano and SHG modes and for this aim we have developed a single ring nano-particle with one and two split ring resonator elements for arousing multi Fano (SHG mode). Exactly, by arousing the Fano and multi Fano modes, the Extinction Cross Section is reduced in comparison with Plasmonic mode based on concentrating energy in the near field. We have shown that the angles of polarization have no effect on the extinction cross-section in multi Fano structure and it is independent of the polarization angle. We have revealed that how the multi Fano would be useful for light trapping and energy harvesting. We have obtained the wider bandwidth for the electric field in comparison with plasmonic and Fano structures which makes our proposed structure useful in energy harvesting applications such as solar cell at higher frequency ranges and an active area for wider bandwidth is achievable. For spectroscopy and optimal imaging, the figure of merit (FOM) is considered as a quality meter for the optical particles. The (FOM) of the external biological materials are compared for all three prototyped plasmonic, Fano and multi Fano structures.**

Index Terms - Plasmonic; Fractal; Second Harmonic Generation; Fano; multi Fano

I. Introduction

Interaction between electromagnetic field and free electrons in metal results a new topic in optical regime which is called plasmonics [1]. In fact, plasmonic wave is made by free electrons in the metal/dielectric interference and with their collective oscillations and movement [2]. These excited free electrons contain charge and energy, so they are called polaritons. Localized surface plasmon polaritons (SPPs) have made plasmonic characteristic based on the metal physic which is studied and modeled by Palik and Johnson [3-4].

Nowadays metamaterial structures because of their left hand attributes have been noticed and developed in various optical devices by novel plasmon injection [5-7].

The Fano resonance is a special form of the spectrum with asymmetric spectral with sharp line and small perturbations can drastically induce variations of intensity or spectrum shifts at this resonance [8]. The Fano resonance is oriented from interaction between subradiant and superradiant modes based on plasmonic in nano-antenna for energy enhancement [9]. Fano-resonant asymmetric metamaterials is noticed for biosensing identification of molecular monolayers and has been described the quadrupole and dipole modes [10].

For achieving Fano resonance, various model of nano antenna in two main groups of symmetrical and asymmetrical shape are noticed such as ring/disk cavity Oligomers [11], hybridized plasmon resonant modes based on bowtie nanoantenna [12] and plasmonic split ring resonator based on the graphene particles [13] for symmetrical formation and intensifying magnetic dark modes in the asymmetric plasmonic quadrumer [14].Split concentric nanoring resonator dimmers for ultra-precise sensing [15] have been are noticed for asymmetrical formations.

Recently, Second harmonic generation (SHG) has been noticed for its specific beneficial application in optical applications [16]. The Second Harmonic Generation using multi Fano Resonances based on heptamers [17], asymmetry in the nanostructure shape for dipole element displacement for Second Harmonic Generation [18] and polarization independent multiple Fano resonances in plasmonic Nonamers for multimode-matching enhanced multiband Second-Harmonic Generation [19] have been studied for energy enhancement in Fano resonance.

This SGH have been used for various applications such as Solar cell application with modified plasmonic nano-antenna [20], absorption spectroscopy of Molecular Monolayers at optical range [21].

In addition, nowadays the Fano independency is noticed in symmetrical structure due to the interaction between these plasmons of dark quad-polar and higher order modes with bright dipolar modes for higher energy enhancement in nano antenna [22].

Metamaterial structure is composite materials that possess unusual electromagnetic properties. The electromagnetic materials forming of them can set with concise and precise manipulation of their structures. This material has made a combination of small bars and a series of metal rings. Unusual properties of these materials have caused them to be used in various fields of microwave engineering that can be used in waveguides, dispersion compensation, smart antennas, lenses and many other examples [23-24].

Recently, Metamaterial in various formations have been noticed for plasmonic multi resonance application in biosensing [25-26] and also they have been noticed for Fano resonance [27-28] and second harmonic generation in optical regime [29]. Split ring resonators are mainly noticed for these applications in different shapes and arrangements [30-31].

Recently, various plasmonic nanoparticle [32] and metamaterial absorber have been also developed in various shapes such as rectangular patch [33] rectangular patch with parasitic based on graphene [34] and multi rings topology [35].