Plasmonic Toroidal Metamaterials at Optical Frequencies

Yao-Wei Huang[1], **Wei Ting Chen**[1], **Pin Chieh Wu**[1], **You Zhe Ho**[1], **Yuan-Fong Chau**[2], **Nikolay I. Zheludev**[3], **and Din Ping Tsai**[1, 4, 5]

[1]Department of Physics and Graduate Institute of Applied Physics
National Taiwan University, Taipei 106, Taiwan
[2]Department of Electronic Engineering, Ching Yun University, Jung-Li 320, Taiwan
[3]Optoelectronics Research Centre and Centre for Photonic Metamaterials
University of Southampton, Southampton SO17 1BJ, UK
[4]Instrument Technology Research Center
National Applied Research Laboratories, Hsinchu 300, Taiwan
[5]Research Center for Applied Sciences, Academia Sinica, Taipei 115, Taiwan

Abstract— Toroidal dipole is created by currents flowing on a surface of a doughnut-shaped structure along its meridians first considered by Zel'dovich in 1957 [1]. Toroidal metamaterials were first theoretically proposed in 2007 [2]. In 2010, the toroidal metamaterials consisted by four three-dimensional resonant split rings show toroidal response in microwave region [3].

In this paper, we study the optical responses by integrating four U-shaped split-ring resonators (SRRs) together. The resonances of the four U-shaped SRRs array with magnetic field of incident light passing through the resonant rings was numerically investigated by using commercial software COMSOL 3.5a based on finite-element method (FEM). The permittivity of gold was described by the Lorentz-Drude model [4]. The size of a single U-shaped SRR is 250 nm (arms) $\times$300 nm (bottom) and 50 nm line width wire loop. Simulation results shows toroidal and magnetic dipole resonance at free space wavelength 2520 nm and 2620 nm respectively. Incident light induced magnetic dipoles point in the same direction produced magnetic resonance. In contrast, four magnetic dipoles form a head-to-tail configuration which concentrates toroidal resonance.

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