BOOSTING THIRD HARMONIC GENERATION IN SILICON METASURFACES

Andrea Tognazzi[1,2], Kirill Okhlopkov[3], Attilio Zilli[4], Davide Rocco[1,2], Michele Celebrano[4], Maxim R. Shcherbakov[3], Monica Bollani[5], Erfan Mafakheri[5], Luca Fagiani[5], Marco Finazzi[4], Andrey Fedyanin[3], Costantino De Angelis[1,2]*

[1] *Department of Information Engineering, University of Brescia, Via Branze 38, 25123 Brescia, Italy*
[2] *CNR-INO (National Institute of Optics), Via Branze 45, 25123 Brescia, Italy*
[3] *Faculty of Physics, Lomonosov Moscow State University, Moscow 119991, Russia*
[4] *Department of Physics, Politecnico di Milano, Piazza Leonardo Da Vinci 32, 20133 Milano, Italy*
[5] *Istituto di Fotonica e Nanotecnologie-Consiglio Nazionale delle Ricerche, Laboratory for Nanostructure Epitaxy and Spintronics on Silicon, LNESS, Via Anzani 42, 22100 Como, Italy*
*a.tognazzi007@unibs.it

In this work we propose a high-quality factor semiconductor nanoparticles array made of rectangular silicon waveguides. Our optimized metasurface can dramatically boost the third harmonic generated signal.
Keywords: silicon metasurface, third harmonic generator.

1. Introduction

Nonlinear optics describes phenomena in which photons with new frequencies are coherently generated when light passes through an optical medium [1,2]. Generally, high-permittivity nanoparticles are emerging as a promising alternative to metallic nanoparticles for a wide range of nanophotonic applications that utilize localized resonant modes [3]. In this work we study the Third Harmonic Generation (THG) coming from a silicon metasurface.

2. Simulations

We perform Finite Element Method simulations in COMSOL Multiphysics. Let us consider a dielectric metasurface made of silicon rectangular waveguide.

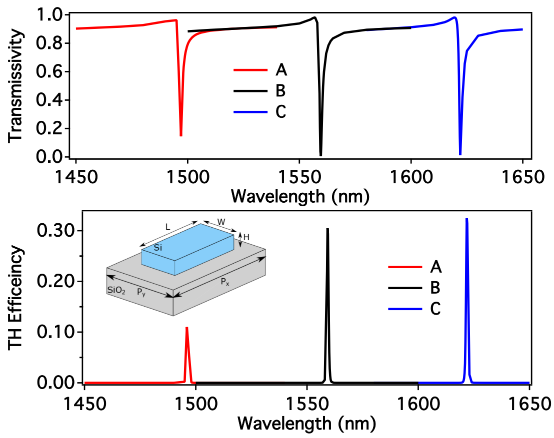

Fig. 1 Transmissivity (Top) and Third Harmonic efficiency (bottom) as a function of the wavelength for different geometrical parameters of the metasurface: (red) P=965 nm W=397 nm L=885 nm, (black) P=1016 nm W=418 nm L=932 nm, (blue) P=1067 nm W=439 nm L=979 nm. The inset represents the unitary cell of the proposed structure.

Each individual element has a height of 125 nm and it is assumed to be place on a substrate of SiO_2.The period of the metasurface is assumed to be square. The parameters of the metasurfaces are optimized to achieve a high Quality factor (Q) mode around the wavelength of the pump, i.e. around 1550 nm. The periodic through-notches that match the momentum of the initially normally incident light to a waveguide mode: $2\pi/p = \beta(\omega)$, where p is the periodicity of corrugations and $\beta(\omega)$ is the propagation constant of the waveguide mode; see the inset of Fig 1. As a result, for the frequencies that satisfy the equation above, strong transmission dips are observed, see Fig.1 a). By changing the width w of the resonators, one can tune the coupling between them, thereby affecting the Q-factor and the spectral position of the resonance. This effect is depicted in Fig 1a), where the Q-factor of the metasurface is plotted as a function of the wavelength for different w values. Finally, we verify that, in the presence of the high Q mode at the fundamental, the THG is enhanced as can be seen in Fig. 1b).

3. Conclusions

In this work, we have demonstrated that it is possible to engineer metasurfaces composed by silicon nanoresonators to achieve high-quality factor resonances at the fundamental wavelength. Such high-Q modes can boost the third harmonic generation efficieny coming from the metasurface.

Acknowledgements

The authors acknowledge financial support from the CNR Joint Laboratories program 2019-2021 and PRIN 2017 Project NOMEN.

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