Second and Third-Order Giant Non-Linear Processes in Plasmonic Metasurfaces

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The performance of many applications in non-linear photonics, such as ultrafast sensing, wave generation, or imaging, has usually been hindered by the small response of conventional non-linear materials [see Boyd, R. Nonlinear Optics 3ed Academic Press (2008)]. Even though the advent of metamaterials has alleviated this situation, thanks to their ability to engineer bulk structures able to overcoming phase-mismatches [see A. Rose, et al. Opt. Mater. Express, **1**, 1232 (2011)] or to increase the efficiency in non-linear processes [see C. Argyropoulus et al. Phys. Rev. B., **89**, 235401 (2014)], their overall non-linear response is still limited. Recently, a new approach based on combining the field enhancement in plasmonic metasurfaces with the intersubband transitions found in engineered quantum-wells has demonstrated second-order susceptibilities orders of magnitude higher than any other non-linear response measured in flat structures [see J. Lee et al, Nature. **511**, 65 (2014)].

In this context, this contribution further explores several second and third-order non-linear processes in this novel type of metasurfaces. Specifically, the non-linear response of the metasurfaces is greatly improved by properly designing subwavelength inclusions able to couple the incoming electromagnetic waves to fields perpendicularly polarized with respect to the quantum-wells, which significantly enhances optical transitions. These novel designs are then applied to investigate i) second harmonic generation, ii) differential frequency generation in the terahertz band, and iii) phase-conjugation. In all cases, the novel plasmonic metasurfaces provide giant and unprecedented non-linear response, fully confirming their suitability as a high-efficient flat platform for non-linear photonics.