TAILORING LIGHT FIELDS WITH NONLINEAR OPTICAL METASURFACES

Thomas Zentgraf
Department of Physics, Paderborn University
Warburger Straße 100, 33098 Paderborn, Germany

Engineering the nonlinear optical properties of media is a crucial process in nonlinear optics. The most well-known technique for spatially engineering the nonlinear properties is quasi-phase matching for second-order processes like SHG. The quasi-phase matching leads to efficient frequency conversion compared to a homogeneous nonlinear medium by providing the extra momentum to compensate the phase mismatch between the fundamental and harmonic waves. The so-called 'poling' is the most widely employed technique for achieving quasi-phase matching. By periodically reversing the crystalline orientation of ferroelectric materials, the sign of the $\chi^{(2)}$ nonlinear susceptibility can be spatially modulated along the propagation direction. However, such a poling only leads to a binary state for the nonlinear material polarization, which is equivalent to a discrete phase change of π of the nonlinear polarization.

Here we will demonstrate a novel nonlinear metamaterial with homogeneous linear optical properties but continuously controllable phase of the local effective nonlinear polarizability. The controllable nonlinearity phase results from the phase accumulation due to the polarization change along the polarization path on the Poincare-Sphere (Pancharatnam-Berry phase) and depends therefore only on the spatial geometry of the metasurface. In contrast to the quasi-phase matching the continuous phase engineering of the effective nonlinear polarizability enables complete control of the propagation of harmonic generation signals, and therefore, it seamlessly combines the generation and manipulation of the harmonic waves for highly compact nonlinear nanophotonic devices. We will demonstrate the concept of phase engineering for the manipulation of the SHG and THG from plasmonic metasurfaces made of subwavelength-size gold nanostructures.

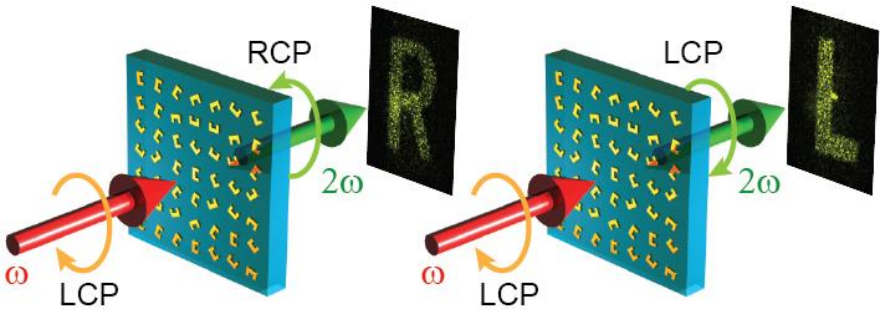

Fig. 1: Nonlinear metasurface hologram in the SHG signal for circularly polarized light.

References:

[1] G. Zheng, H. Mühlenbernd, M. Kenney, G. Li, T. Zentgraf, and S. Zhang, *Metasurface holograms reaching 80% efficiency*, Nature Nanotechnology **10**, 308-312 (2015)

[2] W. Ye et al., *Spin and wavelength multiplexed nonlinear metasurface holography*, Nature Comm. **7**, 11930 (2016).

[3] G. Li, S. Zhang, and T. Zentgraf, *Nonlinear photonic metasurfaces*, Nat. Rev. Mater. **2**, 17010 (2017)