DOCTORAL THESIS

Spin-controlled second harmonic generations on plasmonic metasurfaces

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Abstract

Plasmonic metasurfaces provide a novel platform for designing and implementing optical functional devices with distinguished advantages of their compactness and ultrathin footprint over traditional optical elements. The constituent metallic structures, or so-called "meta-atoms" or "meta-molecule" can interact with light at a subwavelength scale and introduce local modulations over multiple degrees of freedom like amplitude, phase, polarization, etc. The specific functions of the devices are then realized by assembling those meta-atoms together to form a planar interface with predesigned distributions. In this thesis we mainly studied nonlinear plasmonic metasurfaces made of gold meta-atoms for second harmonic generations (SHG). These metasurfaces work in the near infrared regime, and exhibit spin-controlled nonlinear responses due to the nonlinear geometric Pancharatnam-Berry phase-based designs.

Firstly, a quasicrystal metasurface was demonstrated to modulate the far-field second harmonic radiations based on both the local symmetry of the meta-atoms and the global symmetry of the lattice those meta-atoms adhere to. Our designs of the nonlinear optical quasicrystal metasurfaces are based on the well-known Penrose tiling and the newly found bronze-mean hexagonal quasiperiodic tiling. The optical diffraction behaviors are studied in both linear and nonlinear regimes to reveal the effects of local and global symmetries on the far-field radiations.

Secondly, a polarization manipulation metasurface was designed to encode a grayscale image into the polarization profiles of the generated second harmonic waves. We use single meta-atoms to manipulate the polarization directions of the

second harmonic waves into predefined directions. With homogenous intensity profiles, the vectorial second harmonic beam can encode and decode information securely.

At last, we utilized the state-of-the-art nano-kirigami technology to design and fabricate a three-dimensional plasmonic metasurface, which exhibits giant nonlinear circular dichroism in second harmonic generations. The second harmonic generations from the metasurface is much stronger when pumping by right circularly polarized fundamental waves than left circularly polarized ones. Broadband near-unity nonlinear circular dichroism was observed and numerical models were developed to explain the phenomenon.

We believe that our works presented in this thesis enriched the study of plasmonic metasurfaces in the nonlinear optical regimes, and may be used to design novel nonlinear light sources, encryption applications, chiroptical devices, etc.

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