A multilayer metasurface design for efficient dynamic reversal of circularly-polarized asymmetric transmission

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Introduction

Asymmetric transmission (AT) is an unequal transmission phenomenon of electromagnetic waves regarding propagation direction. Historically, AT has been discussed in the context of nonreciprocal transmission. However, AT does not necessarily require nonreciprocity. In fact, AT can also occur in reciprocal systems through the conversion of incident waves into different output modes. Anisotropic metasurfaces effectively achieve such mode conversion between polarizations, enabling reciprocal AT at subwavelength scales. In particular, AT for circular polarization (CP-AT) has been realized using anisotropic or chiral metasurfaces. Recently, the possibility of its dynamic control has been explored. For example, dynamic reversal of CP-AT direction has been experimentally demonstrated [1]. However, its efficiency is limited due to the single-layer design. This study proposes a multilayer metasurface toward the ideal reversal of CP-AT.

Design Method

Figure 1 represents the unit cell of the proposed metasurface. It incorporates a polarization-axis switchable metasurface utilizing vanadium dioxide (VO_2), which exhibits a metal-insulator transition around 68 ℃. The central layer works as a linear polarizer whose polarization axis switches between the $y = x$ or $y = -x$ directions depending on the state of VO_2. During the VO_2 phase transition, the metallic pattern of central layer is transformed into its complementary pattern, which is rotated by 90 degrees from the initial state. Based on Babinet's principle, this special symmetry enables the polarizer-axis switchable response of the central layer. For the highly efficient operation of CP-AT, we optimized the admittance of each anisotropic layer based on transmission line theory [2]. Then, we determined the corresponding patterns to realize the required admittances by the finite element method.

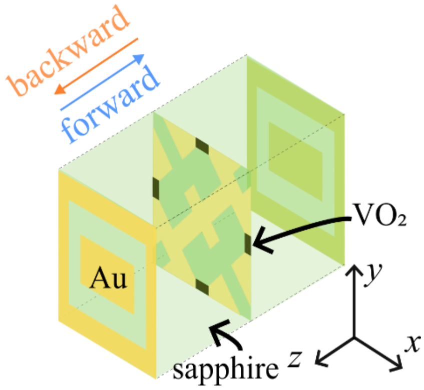

Fig. 1. Schematic of the unit cell.

Results

The efficiency of CP-AT is quantified by the asymmetric parameter ΔT_R, defined as $\Delta T_R = T^f_{LR} - T^b_{LR}$. Here, T^d_{LR} represent the power transmission from an incident right circular polarization to a transmitted left circular polarization for a specific propagation direction d at the normal incidence (f: forward, b: backward). Figure 2 shows the simulated CP-AT efficiency, ΔT_R for the proposed multilayer metasurface. It is seen from the figure that the drastic efficiency improvement with as high as over 95 % in the lossless case in contrast to the previous single-layer metasurface, with the efficiency of approximately 15 %.

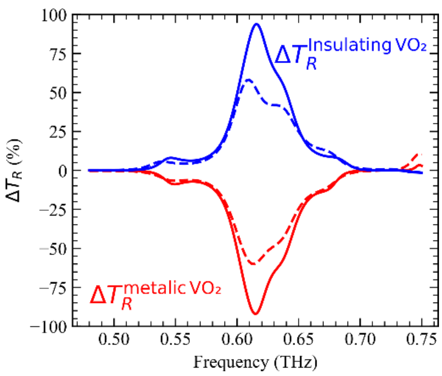

Fig. 2. Simulation results: AT efficiency (solid line: lossless, dotted line: with loss).

References

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