Breaking Malus' Law: Enhancing Asymmetric Light Transmission with Metasurfaces

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Devices providing asymmetric transmission of light are useful components for optical communication systems, information processing and laser applications. In this work, we demonstrate a 290 nm thick metasurface providing asymmetric transmission of light at 1.5 μm with a transmission efficiency of 68% in one direction, and suppressed transmittance (1/24) in the opposite direction, and with broad band characteristics. It consists of three layers of sub-wavelength period metallic grating separated by dielectric layers, and their transmission axes are rotated by 45° with respect to each other (Figure 1a).

The structure is fabricated by E-beam lithography and subsequent gold lift-off [1], whose SEM pictures are shown in figure 1. Device transmittance is measured around 1.5 μm, shown as dotted lines in figure 2. The device has a high transmittance for x-polarized incident light and most of the beam is converted to the y-polarization (T_{yx} ~ 63% at 1.5 μm, where T_{yx} denotes transmission from x-polarized light to y-polarized light). However, most of y-polarized incident light is either reflected or absorbed by this metasurface, as shown by the very low T_{yy} and T_{xy}. We define an extinction ratio as the ratio of T_{yx} to the maximum of T_{xx}, T_{yy} and T_{xy}, and the measured value at 1.5 μm is 11.4:1 (10.6 dB).

According to the Malus' Law, light transmittance through the cascaded three layer system with polarization axis rotated 45° with respect to each other will be weak. Clearly Malus' Law breaks down for such closely spaced three layers of wire grid polarizers, because it is only valid when the reflections between the adjacent layers are negligible. However in this structure, reflection from each layer cannot be neglected and strong interference between the three layers enhances the cross-polarization conversion and leads to strong asymmetric light transmission [2].

1. C. Pfeiffer, C. Zhang, V. Ray, L. J. Guo , A. Grbic, Phys. Rev. Lett., 113, 023902 (2014)
2. N. K. Grady, J. E. Heyes, D. R. Chowdhury, Y. Zeng, M. T. Reiten, A. K. Azad, A. J. Taylor, D. A. R. Dalvit and H. T. Chen, Science, 340, 1304-1307 (2013)

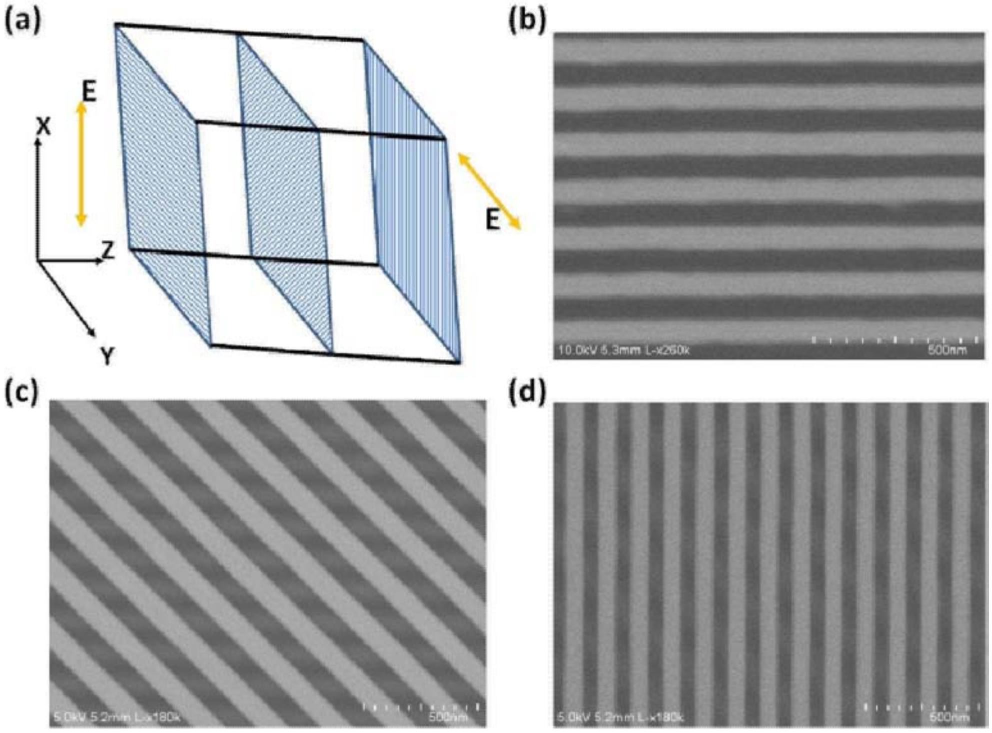

Figure 1: (a) Device schematics; (b-d) Scanning electron micrographs of the bottom (b), middle (c) and top layer (d) of the fabricated structure.

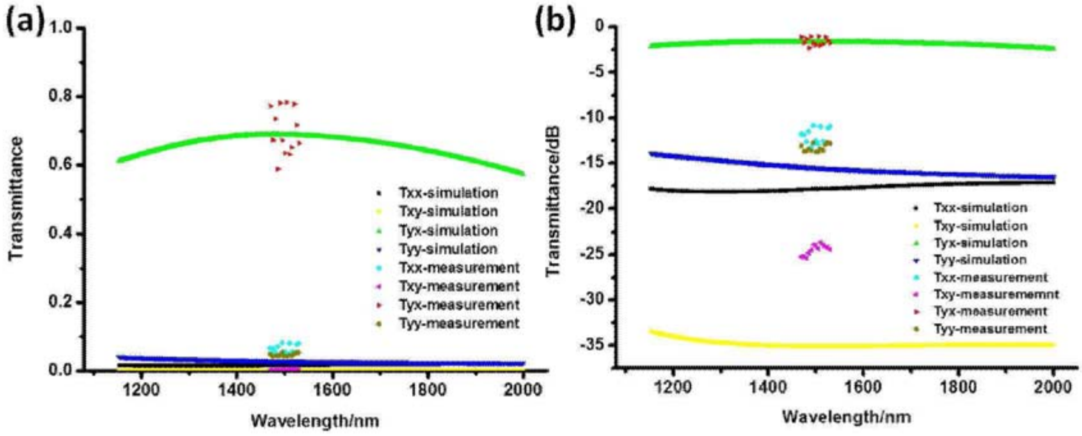

Figure 2: Simulated (solid lines) and measured (dotted lines) of the device transmission in linear (a) and logarithmic (b) scales, showing highly asymmetric transmission behavior. T_{xy} denotes transmission from y-polarized light to x-polarized light here.