www.sciencemag.org/cgi/content/full/science.1214686/DC1

Supporting Online Material for

Broadband Light Bending with Plasmonic Nanoantennas

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Published 22 December 2011 on *Science* Express
DOI: 10.1126/science.1214686

This PDF file includes:

Materials and Methods
Figs. S1 and S2

Materials and Methods

A constituent antenna, which is shown schematically in Fig. S1(A), has two rectangular arms split with an angle α forming a V shape. The arms have length l and width w. The angle between the symmetry center of the antenna and the x axis is β. The thickness of the antenna is h. In our design we used $w = 40$ nm and $h = 30$ nm for all antennas. In a unit cell, the first four antennas have $\beta = 45°$, $\alpha = 60°, 90°, 120°, 180°$, and $l = 158$ nm, 145 nm, 110 nm, 93 nm. The latter four antennas in the unit cell have $\beta = -45°$, and the rest of the parameters are the same as those of the first four antennas. Full-wave simulations using the finite element method (FEM) were performed to ensure accurate designs. The simulated results for the individual antennas as well as the entire antenna array are shown in Fig. S1 (B) and (C), which clearly show that the wave front for cross-polarized light is modified due to the phase discontinuity introduced by the antenna array. The experimentally measured incident-angle-dependent results are shown in Fig. S2.

The nano-antenna array sample was fabricated on a double-side polished silicon substrate with standard electron-beam lithography and lift-off processes. Four large arrays (~ 500×500 μm^2) with different periodicities were fabricated on the same substrate. The sample was measured using the scatterometry mode of a spectroscopic ellipsometer (J. A. Woollam Co., V-VASE). The diameter of the spot of the incident beam was around 450 μm.

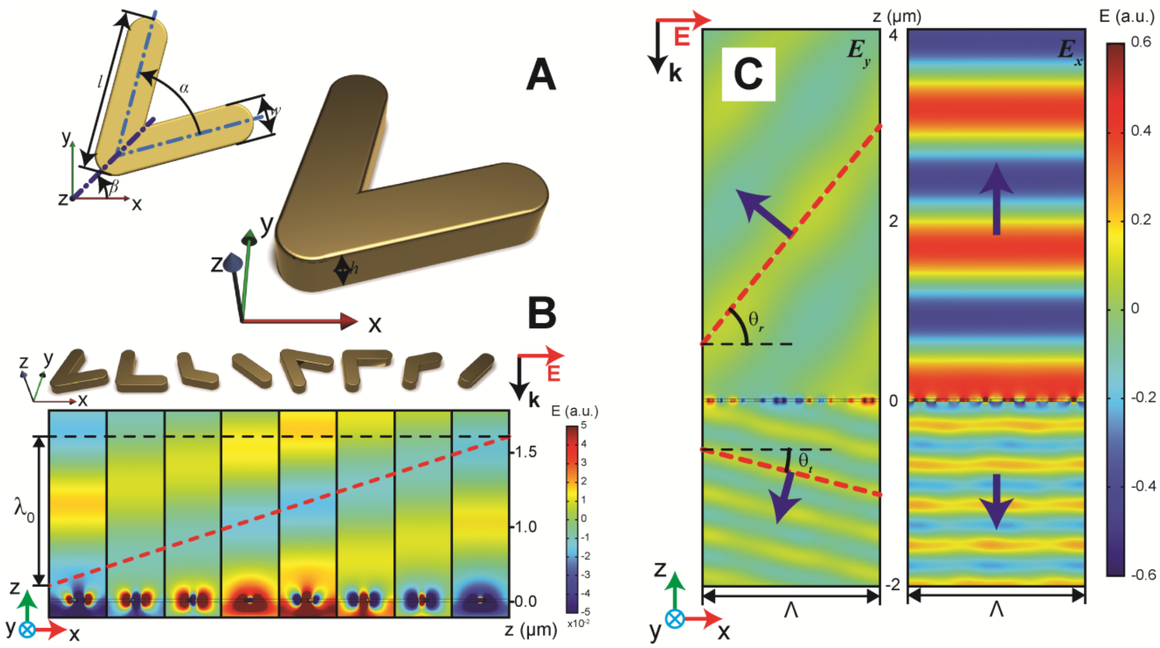

Fig. S1.

(A) Schematic view of a constituent antenna. **(B)** The simulated results for the individual constituent antennas in a unit cell on a silicon substrate using realistic optical properties for the materials as obtained from experiments. The false-color map indicates the cross-polarized electric field at normal incidence from the top of the sample with the incident electric field polarized in the x direction. The red dashed line shows the phase difference between the antennas; the total phase shift from the eight antennas is 2π. **(C)** FEM simulation for the eight antenna array elements. This example shows the antenna array labeled ④ (Λ = 1920 nm). Light is incident from the top with the electric field polarized in the x direction. The left field map shows the cross-polarized electric field. The red dashed line shows the wave front of the scattered light, and the blue arrow indicates the propagation direction. The right field map shows the x-polarized scattered electric field for the same structure, which exhibits ordinary reflection and refraction.

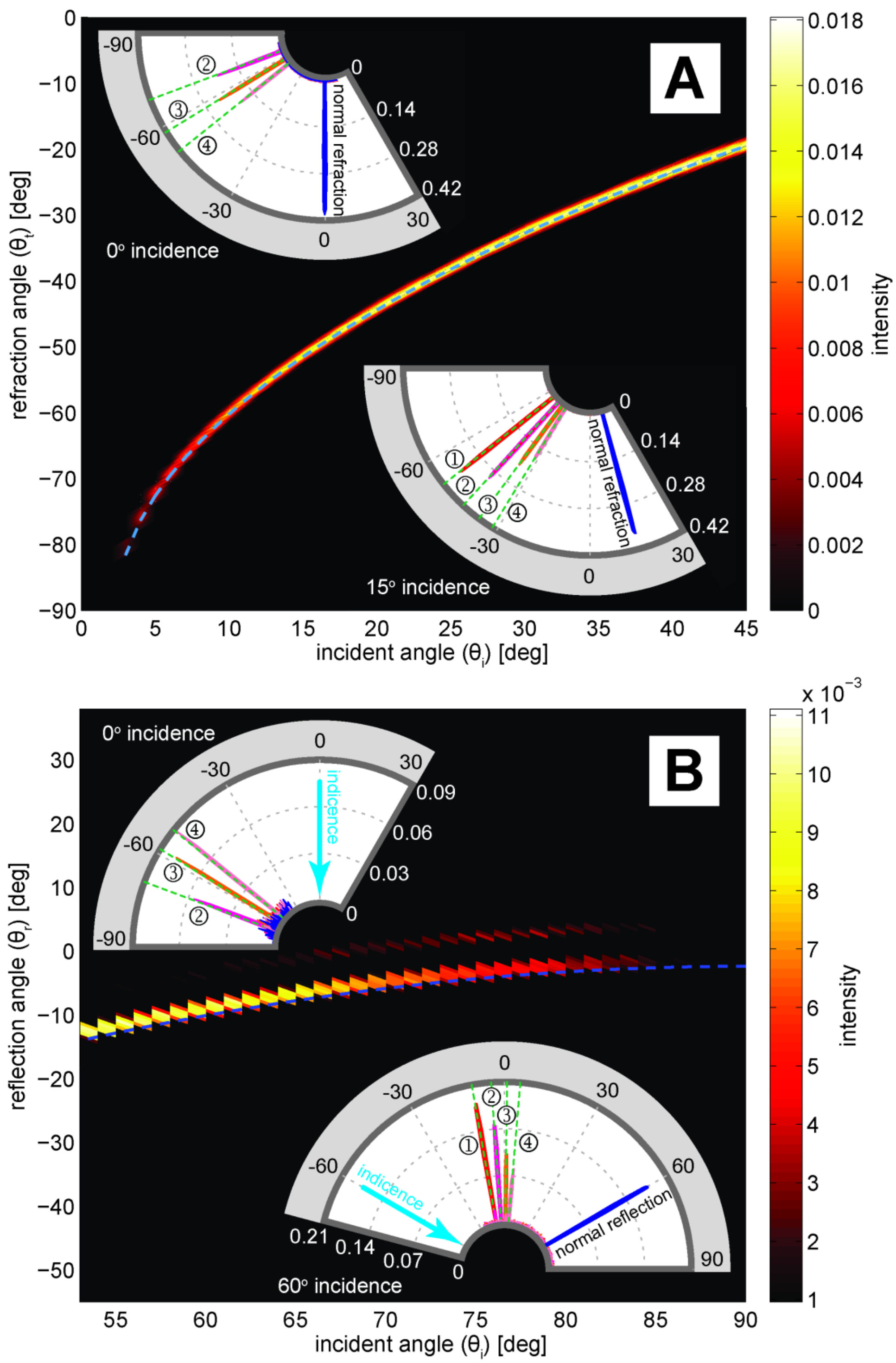

Fig. S2.

False-color maps indicating the experimentally measured relative intensity profiles for the antenna array labeled ① (see Fig. 1**B**, Λ = 1440 nm) with x-polarized excitation. The dashed line shows the theoretical prediction of the peak position using the generalized

Snell's law. **(A)** Refraction angle versus incidence angle for cross-polarized light at a wavelength of 1500 nm. **(B)** Reflection angle versus incidence angle for cross-polarized light at a wavelength of 1500 nm. The insets are the measured data for antenna arrays with different periodicities at 1.5 μm wavelength (the dashed line indicates the theoretical prediction). The cross-polarized light is scaled by a factor of 20 for clarity. For the cases with 0° incidence angle, the cross-polarized light peak for sample ① does not appear since there is no real solution for the refraction/transmission angle and the wave becomes evanescent.