

Polarization-selective Coupling to Long-Range Surface Plasmon-Polariton Waveguides

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Abstract: We use plasmonic antenna arrays to unidirectionally couple incident light in two different polarization states to long-range surface plasmon polariton waveguide modes propagating in opposite directions. The structures enable polarization-sorting with extinction rates in excess of 30dB.

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1. Introduction

Bragg grating couplers are a prevalent design choice for coupling light to optical waveguides, yet they offer limited control over both the direction of propagation of the coupled electromagnetic wave and over the coupled polarization state. A recently demonstrated structure based on arrays of polarization-selective plasmonic antennas [1] addresses these issues by accepting any polarization state on the Poincaré Sphere and by coupling to bound modes propagating in opposite directions depending on the polarization state of the incident light. This enables in particular the unidirectional coupling of circularly polarized states, with left- and right-circularly polarized light being coupled to waves launched towards opposite sides of the structure. We demonstrate here for the first time the implementation of such a structure in a waveguide system at telecommunication wavelengths and characterize the polarization-sorting response in terms of a simple formalism. As a testbed, we employ long-range surface plasmon polariton (LRSPP) waveguides, which consist of nanometer-thin metal strips in a homogenous dielectric environment (Fig 1a). In contrast to conventional surface plasmon polaritons, LRSPPs can achieve centimeter-scale propagation lengths and enable near-perfect mode-matching to optical fibers [2]. The devices were characterized by illuminating the couplers with light of adjustable polarization state from an optical fiber (SMF28) and observing the output at opposite waveguide endfacets with a camera (Fig 1b).

2. Device Response

While in the initial demonstration [1] the coupler coupled to waves bound at a single interface without lateral confinement, the waveguide system introduces reflection and interference effects that distort the polarization response of the coupler taken by itself. To characterize the effective polarization response of the devices we consider the left and right waveguide outputs as independent channels described by Stokes vectors ("device vectors") D_R and D_L . The left and right output intensities I_L and I_R are then given by the projections of the Stokes vector corresponding to the state of the incident light S along the device vectors, i.e. $I_R = S \cdot D_R$ and $I_L = S \cdot D_L$. Fig 1c shows device vectors of the left and right output channels measured at three different wavelengths. Fig 1d displays the normalized left and right outputs of the device as the input polarization traces out full circles around the Poincaré Sphere that include the respective device vectors. The output undergoes a sinusoidal variation corresponding to the projection of the input Stokes vector S on the device vectors. By appropriately choosing the input polarization to be orthogonal to a device vector, it was possible to unidirectionally couple to a single output channel with extinction ratios exceeding 30dB and efficiency comparable to that of a conventional Bragg grating patterned on the same type of waveguide.

3. Conclusion

We demonstrate polarization-selective coupling to LRSPP waveguide modes by implementing a recently developed coupling scheme for the first time in a waveguide system. The technique is capable of polarization-sorting to two counter-propagating output channels, enabling in particular polarization-controlled unidirectional coupling. The effective polarization response of the device can be graphically represented with vectors on the Poincaré Sphere. The

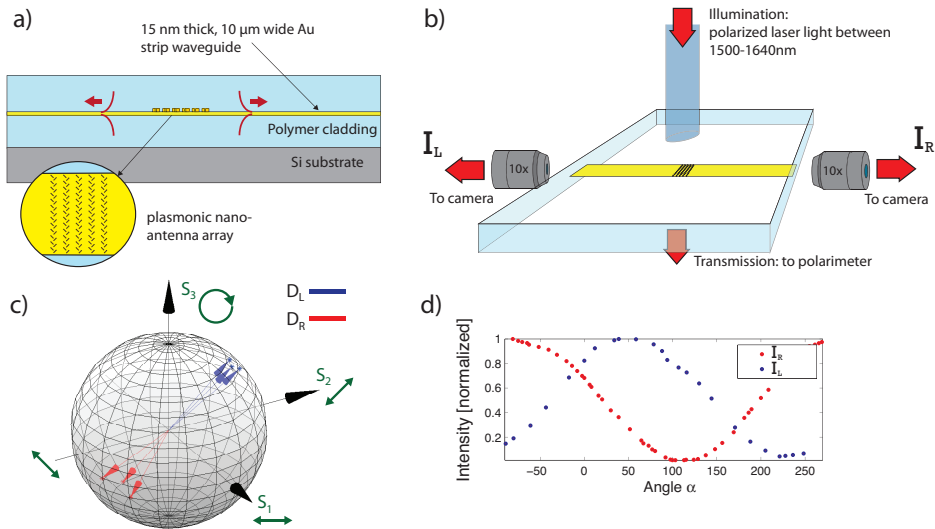


Fig. 1. **a)** A 15 nm thick, 10 μm wide Au strip waveguide is embedded in a polymer cladding that is supported on a Si substrate. The coupler launches long-range surface plasmon polaritons in counter-propagating modes. Inset: top view of the plasmonic antenna array patterned on top of the strip waveguide. **b)** The polarization response of the devices is measured by observing the output at the waveguide endfacets as the coupler is illuminated with light of variable polarization from an optical fiber (SMF28). **c)** The device vectors corresponding to the left (blue) and right (red) output channels on the Poincaré Sphere for 1620 nm, 1630 nm and 1640 nm input wavelength. **d)** Left (blue) and right (red) output intensities as the input polarization is varied to trace out a full circle across the Poincaré Sphere that includes the respective device vector.

enhanced control over the coupling to waveguide systems may pave the way towards optical switches and polarization splitters for integrated optical networks.

References

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