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A subwavelength Stokes polarimeter on a silicon chip

Alba Espinosa-Soria¹, Francisco J. Rodríguez-Fortuño², Amadeu Griol¹ and Alejandro Martínez^{1*}

¹ Nanophotonics Technology Center, Universitat Politècnica de València, Valencia, Spain

² King's College London, Strand, London WC2R 2LS, United Kingdom

* email: amartinez@ntc.upv.es

Abstract

The measurement of the state of polarization (SoP) of a light beam is essential in many scientific and technological disciplines, including astronomy, sensing, or high-speed optical communications. Typically, polarimeters are built using bulky and expensive optical elements - mainly a combination of fixed or rotatable quarter-wave plates and linear polarizers - with little prospects for miniaturization. In the way towards miniaturization down to the nanoscale, it would be highly desirable to build the polarimeter on a photonic integrated circuit that can be fabricated using standard semiconductor fabrication tools. This would enable numerous advantages, such as cost-effectiveness, easy integration with electronics or mass-scale production. A suitable way to reduce the device dimensions to the scale of the wavelength or below is the use of plasmonic nanostructures (1). Recently, nanoscale polarimeters for visible wavelengths relying upon the polarization-sensitive response of plasmonic nanoresonators have been demonstrated (2,3). However, such approaches require resolution down to the 10-nm level, which can be done using ion-beam milling, a fabrication tool not compatible with standard semiconductor fabrication technologies. Here, we introduce and demonstrate a nanophotonic Stokes polarimeter integrated on a silicon chip fulfilling the requirement of fabrication using standard tools and exhibiting other advantages such as extremely small footprint (the active region occupies less than a square wavelength), ultrabroad-bandwidth (in principle, unlimited), and low-insertion losses (to be potentially used in an inline configuration). We use a plasmonic nanoantenna placed on top of the crossing of two perpendicular silicon waveguides. Under normal illumination, the nanoantenna scatters part of the incoming radiation into guided optical power. Remarkably, the evanescent tails of the waveguide modes exhibit an intrinsic quantum spin Hall effect (QSHE) of light (4), so the scattering process will be mediated by a strong spin-orbit coupling effect (5). This results in a polarization-sensitive response of the nanoantennas (6) that, unlike in (2,3), does not rely on complex nanoscale shaping of metallic surfaces, which enormously facilitates fabrication. By measuring the optical power at each output port, we are able to reconstruct the SoP of the incoming signal, which is demonstrated experimentally at telecom wavelengths. We also demonstrate the polarimetric method by using a hole created on the waveguide crossing, so the device is built on a single lithographic step, also removing the use of metals. This nanophotonic

device could pave the way to on-chip ultracompact polarimeters capable to produce real-time measurements of the SoP, which could find applications in a wide variety of scientific and technological disciplines.

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