# Arbitrary polarization conversion dichroism metasurfaces for full Poincaré sphere polarizers

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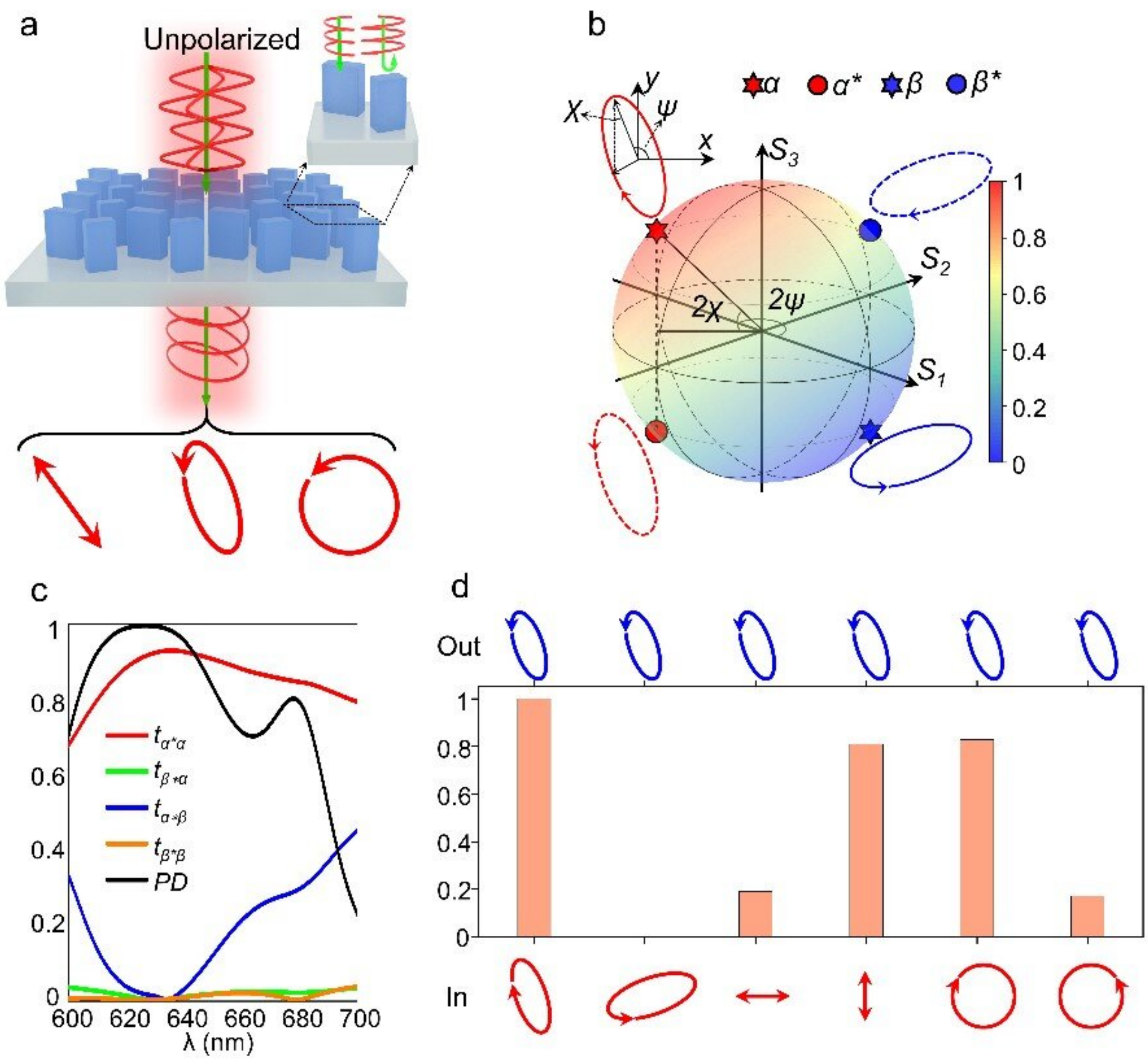


a, Schematic of the proposed all-in-one polarizer that can function at an arbitrary position on the Poincaré sphere by design based on a dielectric metasurface composed of dimerized nanopillars, which can directly operate with unpolarized incident light and generate arbitrary polarization states, including linear, elliptical and circular polarizations, regardless of the incident polarization state. b, Poincaré sphere representation of an arbitrary orthogonal polarization pair (α, β) (solid red and blue ellipses) and its handedness-flipped pair (α*, β*) (dashed red and blue ellipses). c, Polarization conversion coefficients and PD spectrum calculated with the optimized parameters (l1=130 nm, w1=70 nm; l2=150 nm, w2=85 nm) at a wavelength of 633 nm, which yields tα*α=0.93 and tβ*α=tα*β=tβ*β?0. d, Transmitted polarization states (blue ellipses) when the metasurface was illuminated by a variety of different incident polarization states (red curves). The histogram indicates the transmittance, which varied with the incident polarization, while the shape of the blue ellipse was the same as that of the designed polarization state α* Credit: Shuai Wang, Zi-Lan Deng, Yujie Wang, Qingbin Zhou, Xiaolei Wang, Yaoyu Cao, Bai-Ou Guan, Shumin Xiao, Xiangping Li

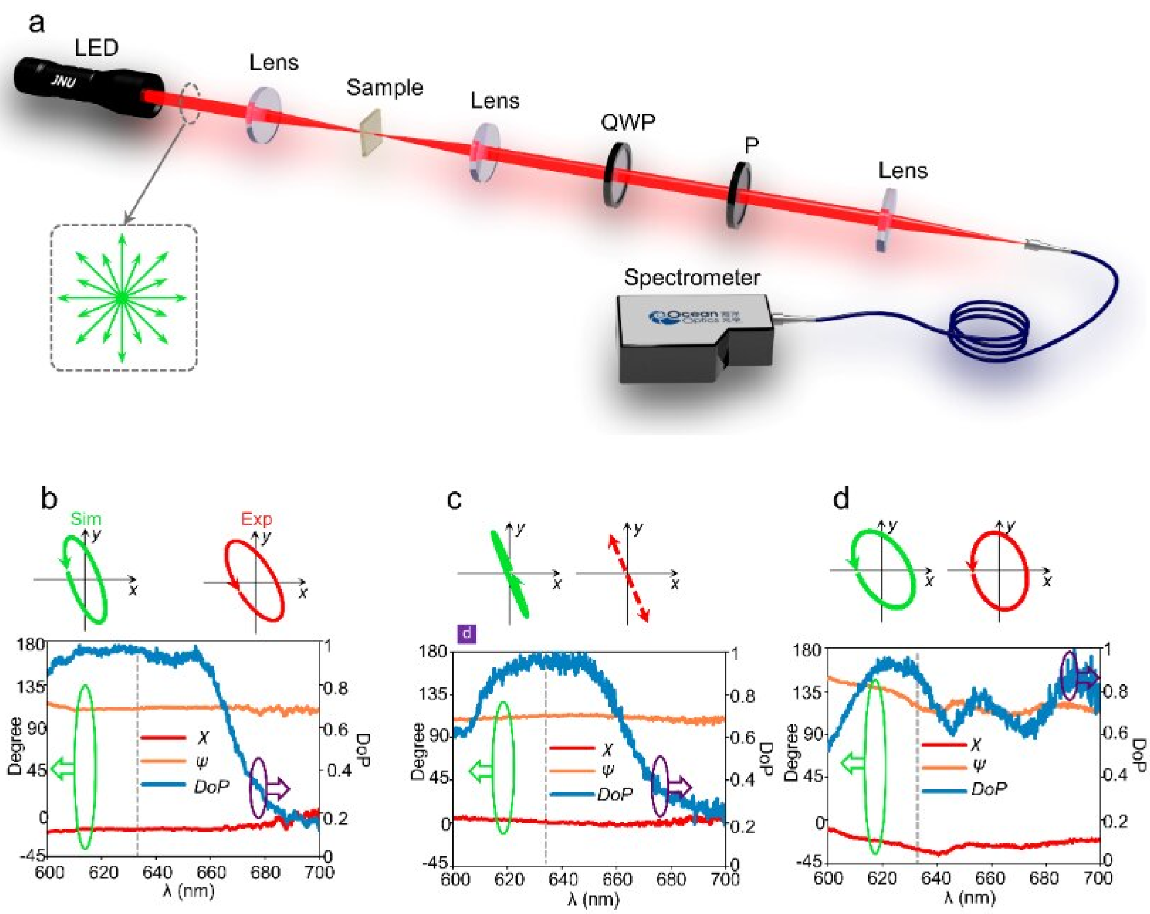
Polarization control is essential for tailoring light-matter interactions and is the foundation for many applications such as polarization imaging, nonlinear optics, data storage, and information multiplexing. A linear polarizer, which is a polarization optical element that filters a specific linear polarization from unpolarized light, plays an important role in both polarization generation and manipulation. However, the generation of arbitrary polarization states other than linear polarization usually requires cascading of multiple optical polarization elements, including both linear polarizers and waveplates based on anisotropic materials or nanostructures, leading to bulky optical systems that are far from the long-sought miniaturization and integration.

In a new paper in *Light Science & Applications*, a team of scientists, supervised by Prof. Xiangping Li and Zi-Lan Deng from Guangdong

Provincial Key Laboratory of Optical Fiber Sensing and Communications, Institute of Photonics Technology, Jinan University, China and co-workers have proposed an effective approach to achieve full Poincaré sphere polarizers in one step by extending circular conversion dichroism (CCD) to arbitrary polarization conversion dichroism (APCD) by means of a monolayer metasurface.

By using dimerized meta-molecules composed of a pair of birefringent meta-atoms with properly tailored anisotropic phase responses and relative orientation angles, the collective interference of far-field radiation from those meta-atoms can be controlled to generate APCD. This system is able to preferentially transmit one polarization state that can be located at an arbitrary position on a Poincaré sphere and convert it into transmitted light with flipped handedness while completely blocking the orthogonal polarization state. This APCD metasurface is capable of generating an arbitrarily polarized beam located at an arbitrary position on the Poincaré sphere, irrespective of input polarization, and thus acts as a polarizer that can cover the full Poincaré sphere by design.

In practice, we realize such APCD in an all-dielectric metasurface platform in the visible frequency range, manifesting transmissive polarization dichroism (PD) of nearly 100% in theory and greater than 90% experimentally. We exploit the perfect PD feature of this system to demonstrate arbitrary polarization, including linear, circular and elliptical polarization, directly from unpolarized light. This all-in-one metasurface polarizer serves as a monolithic arbitrary polarization generator, ultimately promising miniaturized optical devices for integrated nanophotonic systems with substantially reduced complexity. These scientists summarize the operational principle of their Poincaré sphere polarizer:




a, Experimental setup for the degree of polarization (DoP) measurement of transmitted light from APCD metasurfaces illuminated by an unpolarized LED source. b-d, Measured main axis angle ψ, ellipticity angle χ and DoPs of the transmitted beams through the designed (b) elliptical, (c) linear and (d) circular dichroism metasurfaces. The green polarization ellipses represent polarization states derived from measured Stokes parameters at 633 nm, which are consistent with the simulated states (red arrows). Credit: Shuai Wang, Zi-Lan Deng, Yujie Wang, Qingbin Zhou, Xiaolei Wang, Yaoyu Cao, Bai-Ou Guan, Shumin Xiao, Xiangping Li

"We design arbitrary state polarizers based on arbitrary polarization conversion dichroism without consideration of incident polarizations: (1) Analyzing the Jones matrix of the planar metasurface realizing the arbitrary polarization conversion dichroism; (2) Applying the Jones matrix in diatomic dielectric metasurface with carefully tailored geometric parameters; (3) Demonstrating the generated polarization without influences from input beams."

"The dichroism parameter is near 100% in simulation and greater than 90% experimentally, this perfect performance make the designed metasurface works as polarizer for arbitrary polarization, even on an unpolarized beam," they added.

**More information:** Shuai Wang et al, Arbitrary polarization conversion dichroism metasurfaces for all-in-one full Poincaré sphere polarizers, *Light: Science & Applications* (2021). DOI: 10.1038/s41377-021-00468-y

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