Spin Orbit Interactions of Light in Photonic Materials

Graciana Puentes[1,2,]

1-Departamento de Física, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Ciudad Universitaria, Buenos Aires 1428, Argentina

2-Instituto de Física de Buenos Aires (IFIBA), Universidad de Buenos Aires-CONICET, Ciudad Universitaria, Buenos Aires 1428, Argentina

Email: gpuentes@df.uba.ar

***Abstract*—In this talk, I will present recent advances in Spin Orbit Interactions (SOIs) of light in photonic materials. In particular, I will review current progress in Spin Hall Effect (SHE) of light and Spin Orbit Conversion (SOC) of light in 2D metamaterials and metasurfaces. Furthermore, I will present an overview of exciting future directions for applications of SOIs of light in next-generation photonic devices, as fundamental constituents of the fast growing field of photonic precision metrology and sensing.**

Keywords—Spin-orbit interactions of light, spin Hall effect of light, orbital angular momentum of light, spin-based photonics, nanostructures, metamaterials, singular optics, nano-optics, quantum optics

Spin-Orbit Interactions (SOIs) of light encompass a broad range of effects that result from the coupling of polarization (i.e., spin) and angular (i.e., orbital) degrees of freedom of light. Because of their fundamental origin and wide-ranging nature, SOIs of light have become inherent in a broad range of active areas, ranging from nano-optics, singular optics, photonics, metamaterials, or quantum optics when dealing with SOIs at the single-photon level. Among a large number of rich exotic phenomena, SOIs exhibit Spin Orbit Conversion (SOC) of light and the so-called Spin Hall Effect (SHE) of light, a remarkable spin-dependent transverse shift of light intensity.

In this talk, I will present an overview of novel results and future directions for applications of SHE of light in photonic materials. As a photonic analogue of the SHE in electronic systems, photonic SHE warrants unique potential for exploration of the physical properties of novel photonic materials and nanostructures, such as in determining the material properties of magnetic and metallic thin films, or the optical properties of atomically thin two-dimensional metamaterials, with unprecedented spatial and angular resolution; a feature than can be achieved by combining SHE with quantum weak measurements and quantum weak amplification techniques.

In addition, I will present an overview of recent advances in 2D metamaterials and metasurfaces and their major applications in generation and manipulation of Spin Angular Momentum (SAM) and Orbital Angular Momentum (OAM) of light.

2D metamaterials, also known as metasurfaces, is an emerging interdisciplinary field which promotes the use of alternative approaches for light engineering based on subwavelength-thick metasurfaces built upon metaatoms, with spatially varying compositions. They exhibit remarkable properties in maneuvering light at a 2D interphase. Metasurfaces cannot only achieve the functionalities of the 3D counterparts, such as negative refractive index and invisibility cloaking but they can also resolve some of the current limits present in 3D metamaterials, such as dielectric loss or high resistive (ohmic) loss. Furthermore, metasurfaces can be easily fabricated via standard nanofabrication approaches, such as electron-beam lithography, processes readily available in the semiconductor industry.

In summary, SOIs of light in photonic materials is a fast growing interdisciplinary field, with significant applications in nanophotonics, biophysics, plasmonics, quantum optics or telecommunication. To a large extent, SOIs warrant precise control of optical fields with unprecedented flexibility and performance. In addition, the reduced dimensionality of photonic metamaterials and metasurfaces enables applications that are distinctly different from those achievable with standard bulk metamaterials. By and large, photonic materials can provide for a novel tool for observation of SHE, generation and conversion of SAM and OAM, a feature which can promote novel applications in next-generation photonic devices, towards precision metrology and sensing beyond state of the art.

Selected References

[1] Spin-Hall effect and circular birefringence of a uniaxial crystal plate, KY Bliokh, CT Samlan, C Prajapati, G Puentes, NK Viswanathan, F Nori, Optica **3** (10), 1039-1047 (2016).

[2] Enhanced spin Hall effect of light by transmission in a polymer, O Takayama, and G Puentes, Optics Letters **43** (6), 1343-1346 (2018).

[3] Photonic spin Hall effect in hyperbolic metamaterials at visible wavelengths, O Takayama, J Sukham, R Malureanu, AV Lavrinenko, and G Puentes, Optics letters **43** (19), 4602-4605 (2018). **Selected for Editor's Pick 2018.**

[4] Spin-Orbit Interaction of Light in Metamaterials and Metasurfaces, G. Puentes, invited review Quantum Reports **1**, 91-106 (2019).