Preface

Plasmonics — the branch of science studying light-driven collective oscillations of charge carriers in materials – has matured significantly during the last few decades. Applications enabled by plasmonics span many areas of science and technology including cancer research, sub-resolution imaging, classical and quantum communications, ultra-sensitive bio(chemical) sensing and spectroscopy, renewable energy generation, and nanoscale heat management. The majority of the conventional applications of plasmonics make use of the well understood phenomena of extreme light localization and the high density of optical states in metal nanostructures and materials. However, a new field has recently emerged where plasmonic effects are used to harness and manipulate photon angular momenta. With the field still in its infancy, understanding the unique role of plasmonics in this new area is just beginning to form.

This book focuses on two types of angular-momentum-sensitive light-matter interactions enhanced by plasmonics – *chirooptical and vortical effects*. *Chirooptical effects* arise in the scattering of light carrying angular momentum (e.g., left- or right-handed circularly polarized light) by chiral objects, i.e., objects that cannot be superimposed onto their mirror images through any rotation. Molecular chiroptical effects are typically very small due to a large mismatch in length scales between the wavelength of light and the molecule size, but can be dramatically enhanced via plasmonic effects on chiral metal nanostructures. *Vortical effects* – molding and recirculating the optical powerflow around a landscape of phase singularities within the electromagnetic field – can also be generated by light interaction with specially-designed plasmonic nanostructures or materials. Plasmonic vortical effects include generation of twisted light – optical beams with orbital angular momentum – as well as trapping and guiding optical energy via a sequence of coupled nanoscale optical vortices 'pinned' to plasmonic nanostructures.

Recent studies have proven that plasmonic nanostructures can both harness and generate angular momentum of light. The different optical response of chiral plasmonic nanostructures to light beams with different spin angular momenta shows great promise in molecular imaging. Plasmonic nanostructures, metasurfaces, and metamaterials also offer unique nanoscale solutions to the generation of beams with orbital angular momentum and to the development of new types of optical-vortex-pinning light trapping platforms. On the other hand, light carrying angular momentum can be used to fabricate new types of plasmonic and photonic nanostructures with novel complex geometries and unusual symmetry properties.

This book is a collective effort by several international research groups to push the frontiers of plasmonics research into the emerging areas of plasmonics-enabled chiral and vortical effects. The book is a collection of 15 chapters written by the leading experts in the field of photonics and plasmonics. The chapters cover various aspects of chiral and singular nanoplasmonics including electromagnetic analysis and design of new plasmonic nanostructures and materials, discovery of novel physical effects, development of nanofabrication and characterization techniques, and expansion of plasmonics into new application domains. Chapters 1-7 focus on novel plasmonics-enabled chirooptical effects and chapters 8-15 detail the physics and applications of vortex-trapping and vortex-generating plasmonic components.

The discussion of the plasmonic-enhanced chirooptical effects starts in Chapter 1, where Zhiyuan Fan and colleagues discuss design and applications of chiral nanostructures supporting plasmon and exciton resonances. The authors predict several mechanisms to transfer and induce circular dichroism in the visible wavelength range using plasmonic nanostructures.

Aurelien Drezet and Cyriaque Genet review fundamental optical properties associated with chiral nanoplasmonic systems via a rigorous algebraic approach in Chapter 2. The authors reveal the underlying relation between the concepts of chirality and reciprocity, which define global classes of chiral elements.

Chapter 3, by Yang Zhao and colleagues, focuses on modeling the physical mechanisms behind extrinsic chiral effects induced in plasmonic metasurfaces and metamaterials, and explores potential new applications of these effects.

In Chapter 4, Vasily Klimov and Dmitry Guzatov discuss the radiation of optically active molecules in various chiral meta-environments. The authors demonstrate a high level of control over their emission characteristics, paving the way for potential applications of chiral nanostructures in drug discovery and mass production.

H.Q. Li and colleagues demonstrate new types of helical photonic crystals with unique photonic dispersion characteristics in Chapter 5. The authors show robust transport of light via chiral photonic guided modes, which is immune to scattering by isotropic homogenous impurities and is phenomenologically similar to robust transport of electrons in topological insulators.

In Chapter 6, Shunping Zhang and Hongxing Xu introduce chiral collective electron motions associated with electromagnetic waves sustained on the metal-dielectric interface of a 1D nanowire. The authors discuss potential applications of such chiral surface plasmon polariton waves in enhancing chirooptical effects and in boosting the information transmission capacity of plasmonic networks.

Chapter 7, by Il Min Lee and co-workers, discusses the surface-plasmon-enhanced chirooptical effects in light scattering on metallic apertures with chiral shapes or distributions. The authors demonstrate conversion of the spin angular momentum of the incident light into the orbital angular momentum of light transmitted through a metallic plate with a chiral aperture pattern.

The second part of the book, focusing on the phenomena of optical singularities and vortical effects in nanoplasmonics, starts with Chapter 8 by Jonathan Tong and colleagues. The authors show that formation of optical vortices is a hidden mechanism behind many unique characteristics of surface plasmon polariton modes and reveal that global topological transitions in hyperbolic metamaterials are governed by the re-arrangement of local topological phase singularities.

In Chapter 9, Boris Luk'yanchuk provides the link between two well-known interference phenomena associated with the scattering of light – Fano resonances and optical vortices – and demonstrates that Fano resonances are accompanied by the generation of optical vortices with the characteristic core size well beyond the diffraction limit.

Takashige Omatsu and Ryuji Morita propose a new approach to next-generation materials processing with vortex laser beams in Chapter 10. The authors demonstrate that optical vortices can twist material to fabricate chiral nanostructures for potential applications in nanoscale imaging for selective identification of the chirality and optical activity of molecules and chemical composites.

In Chapter 11, Luca Dal Negro and colleagues present their work on the generation of twisted light beams by using aperiodic arrays of plasmonic nanoparticles arranged into spiral geometries. The authors demonstrate the successful encoding of specific numerical sequences, determined by the aperiodic geometry, with the azimuthal angular momentum values of diffracted optical beams.

Chapter 12, by Reuven Gordon, discusses the use of vortex electron beams with orbital angular momentum to experimentally probe magnetic plasmons at the nanometer scale. This is in analogy to the local probing of plasmonic resonances by monitoring how fast electrons lose their energy to metal nanostructures.

Wei Ting Chen and colleagues demonstrate formation of an optical vortex in the near field region of a low-symmetry plasmonic nanostructure with a Taiji pattern in Chapter 13. The authors study the vortex-induced optical torque for potential applications in the opto-mechanical oscillators.

In Chapter 14, Samel Arslanagić and colleagues review interesting effects in light manipulation with passive and active core-shell nano-particles. The authors provide design rules for engineering nano-scatterers with cross sections significantly larger than their geometrical size, and nano-antennas that can either amplify or jam the emission of localized dipole sources.

Chapter 15, by Remo Proietti Zaccaria and co-authors, closes the volume with a broad discussion of applications that exploit surface plasmon generation, propagation and concentration. The authors reveal the role of optical singularities in the process of adiabatic compression, which allows the concentration of energy and the induction of high intensity electric and magnetic fields in nanoscale regions.

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the subject via stimulating discussions, and the Pan Stanford editorial team for their hard work in bringing the book to the readers.

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