

Nanophotonics

Manipulating Light with Plasmons

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Nanophotonics: Manipulating Light with Plasmons

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Contents

<i>Preface</i>	ix
1. Fundamentals of Plasmonics	1
<i>Lianming Tong, Hong Wei, and Hongxing Xu</i>	
1.1 Introduction	1
1.2 Dielectric Function of Metal	2
1.3 Localized Surface Plasmons	5
1.3.1 Quasi-Static Approximation	5
1.3.2 Extinction, Scattering, and Absorption	7
1.3.3 Near-Field Distribution	8
1.3.4 Decay of Localized Surface Plasmons	9
1.4 Propagating Surface Plasmons	10
1.4.1 Propagating Surface Plasmons at the Planar Metal–Dielectric Interface	10
1.4.2 Length Scales of Propagating Surface Plasmons	12
1.5 Research Topics	14
2. Light Scattering by Small Metallic Particles: Mie Theory and More	21
<i>Shunping Zhang and Hongxing Xu</i>	
2.1 Light Scattering by a Single Spherical Particle and Mie Theory	23
2.1.1 Vector Solutions in the Spherical Coordinate: VSH	23
2.1.2 Expansion of a Plane Wave by VSH	25
2.1.3 Scattering by a Single Sphere	27
2.1.4 Optical Far-Field Cross Sections	29
2.2 Generalized Mie Theory	31
2.2.1 Scattering by a Multilayered Sphere	32
2.2.2 Addition Theorem for VSH	35
2.2.3 Order-of-Scattering Method for Two Spheres	37
2.2.4 Order-of-Scattering Method for an Arbitrary Number of Spheres	40

2.3	Light Scattering by Arbitrarily Shaped Particles and Numerical Simulations	46
2.3.1	The Green Dyadic Method	47
2.3.2	Numerical Techniques	49
2.4	Summary	51
3.	Electromagnetic Field Enhancement in Surface-Enhanced Raman Scattering	55
	<i>Ke Zhao, Hong Wei, and Hongxing Xu</i>	
3.1	Introduction	55
3.2	Numerical Approaches to EM Enhancement	57
3.3	The Nanogap Effect	60
3.4	Various Types of Nanogaps	68
3.5	Multiple-Particle Nanoantennas for Controlling Polarization of SERS Emission	76
3.6	Electronic Coupling in Nanogaps	77
3.7	Probing EM Enhancement via SERS	79
3.8	Summary	81
4.	Plasmonic Antennas	85
	<i>Zhipeng Li, Longkun Yang, Hancong Wang, and Hongxing Xu</i>	
4.1	Introduction	85
4.2	Single Plasmonic Antennas	86
4.3	Coupled Optical Antennas	93
4.3.1	Control of Local Intensity	93
4.3.2	Control of Emission Direction	96
4.3.3	Control of Far-Field Polarization	98
4.4	Summary	104
5.	Plasmon-Assisted Optical Forces	109
	<i>Lianming Tong and Hongxing Xu</i>	
5.1	Introduction	109
5.2	Theoretical Calculations on Optical Forces in Near-Field-Coupled Nanoparticles	111
5.3	Experimental Demonstrations of Plasmon-Assisted Optical Forces	117

5.3.1	Optical Forces on Metal Nanoparticles Trapped by a Focused Laser Beam	117
5.3.1.1	Elongated nanoparticles	117
5.3.1.2	Interaction between two metal nanoparticles in an optical trap	121
5.3.1.3	Applications in SERS sensing	124
5.3.2	Optical Forces in Lithographically Fabricated Plasmonic Nanostructures	127
5.3.2.1	Gold nanopads and nanoholes	127
5.3.2.2	Dimers of nanodisks	128
5.3.3	Optical Forces in Propagating Surface Plasmon Systems: Gold Thin Films and Nanostripes	130
5.4	Summary and Perspective	132
6.	Plasmonic Nanowire Waveguides and Circuits	137
	<i>Hong Wei and Hongxing Xu</i>	
6.1	Introduction	137
6.2	Excitation and Detection of Propagating SPPs	139
6.2.1	SPP Excitation	139
6.2.2	SPP Detection	141
6.3	Fundamental Properties of SPPs in Metal Nanowires	145
6.3.1	SPP Modes in Metal Nanowires	145
6.3.2	SPP Propagation in Metal Nanowires	149
6.3.3	Group Velocity	158
6.3.4	Propagation Length and Loss	159
6.3.5	Emission Direction and Polarization	164
6.3.6	Spin–Orbit Interaction of Light in Plasmonic Nanowires	171
6.3.7	Nanowire–Emitter Coupling	173
6.4	Plasmonic Devices and Circuits	177
6.4.1	SPP Router, Splitter, Demultiplexer, Switch, and Spin Sorter	177
6.4.2	SPP Modulation, Logic Gates, and Computing	185
6.4.3	Hybrid Plasmonic-Photonic Nanowire Devices	192
6.5	Summary	194

7. Gain-Assisted Surface Plasmon Resonances and Propagation	201
<i>Ning Liu and Hongxing Xu</i>	
7.1 Introduction	201
7.2 Amplification of Long-Range Surface Plasmon Polaritons	203
7.3 Stimulated Emission from Localized Surface Plasmon Resonance with a Gain Material	206
7.4 Gain-Assisted Hybrid Surface Plasmon Propagation: Lasing and Amplification	212
7.4.1 Hybrid Surface Plasmon Lasers	212
7.4.2 Amplification of Hybrid Surface Plasmon Polaritons	218
7.5 Summary and Future Perspective	221
<i>Index</i>	225

Preface

Manipulation of light at the nanometer scale is highly pursued for both fundamental sciences and wide applications. The related studies are within the scope of nanophotonics. The diffraction limit of light sets the limit for the smallest size of photonic devices to the scale of light wavelength. Fortunately, surface plasmons (SPs), collective oscillations of electrons at the surface of metal (mostly gold and silver) nanostructures, make it possible to squeeze light into nanoscale volumes and realize light manipulation beyond the diffraction limit.

SPs were discovered and formally named more than a half century ago, although the phenomena related to SPs appeared much earlier. They attracted renewed interest, and there was explosive growth in the 21st century due to the developments in nanostructure fabrications, characterizations, and simulations. The studies on SPs have formed a booming research field called plasmonics, which is concerned with the phenomena, mechanisms, devices, and applications based on SP resonances mostly in metallic and composite nanostructure systems.

Historically, two plasmon-related research topics predate the prosperity of plasmonics, surface-enhanced Raman scattering (SERS) and surface plasmon resonance (SPR) sensing. SERS, discovered in the 1970s, is caused by SP-induced electromagnetic field enhancement. Especially, the hugely enhanced electric field in the nanogap of a nanoparticle dimer reported in 1999 reveals clearly the mechanism of single-molecule SERS and demonstrates the most charming character of SPs in coupled metal nanostructures. The field enhancement effect in nanogaps has been widely used to enhance various light-matter interactions. The SPR sensing developed in the 1980s utilizes the SP resonances of metal films deposited on glass substrates. Their high sensitivity to the environmental change and easy fabrication procedure bring about the commercial application of SPR sensor chips.

Plasmon-based nanophotonics has potential applications in many fields, such as information technology, biological/chemical sensing, medical diagnosis and therapy, renewable energy, and

super-resolution imaging. Field confinement beyond the diffraction limit enables the scaling down of photonic devices and facilitates the integration of nanophotonic devices with nanoelectronic devices. Due to its various potential applications, plasmonics attracts researchers in different fields, including physics, materials, biology, chemistry, and medicine, which makes plasmonics a truly interdisciplinary field.

The continually emerging research topics bring vitality to this field. For example, quantum plasmonics is developing quickly. On the one hand, quantum effects occur when the size of the nanogap is decreased to a few angstroms. On the other hand, quantum optics phenomena, such as quantum entanglement and quantum interference, are realized in plasmonic systems. Graphene plasmonics extends the plasmonic materials from metal to novel 2D materials. Plasmons have been involved in the studies of chemical reactions, leading to the creation of a new field, plasmochemistry. Plasmonic circular dichroism and various chiral and vortical effects form the field of chiral plasmonics. Photonic spin-orbit interactions and resulting novel optical phenomena in plasmonic nanostructures have been investigated recently.

This book gives a general introduction to the fundamental aspects of plasmonics. Chapter 1 presents a brief introduction to the fundamentals of localized SPs and propagating SPs and outlines the most active research topics. In Chapter 2, the computational approaches to light scattering due to SP resonances in metal nanoparticles are introduced. Chapters 3–5 cover three of the typical subfields resulting from SP resonances in metal nanoparticles: SERS, plasmonic nanoantennas, and plasmon-assisted optical forces. Chapter 6 focuses on propagating SPs in nanowire waveguides for controllable subwavelength light guiding and potential circuitry applications. Chapter 7 introduces the optical properties in plasmonic systems with gain materials.

Plasmonics is still developing fast, and new research topics keep emerging. This book is not intended to cover all aspects of plasmonics but gives some introduction to the fundamental and representative properties and research in this field, which can help graduate students and researchers get a quick study of this field and get the necessary information to step toward new research.

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