DOWNLOAD PDF NANOPHOTONICS WITH SURFACE PLASMONS

Chapter 1 : Issue 4 () â€“ Nanophotonics

Current developments in optical technologies are being directed toward nanoscale devices with subwavelength dimensions, in which photons are manipulated on the nanoscale.

The evolving field of nanophotonics seeks to combine the capabilities of nanotechnology and photonics. Bozhevolnyi, Aalborg Universitet, and Vladimir M. Shalaev, Purdue University In this first of two articles on optical technologies that manipulate photons at the nanoscale, we discuss how surface plasmons are analogous to photons and how they may be used to efficiently guide and control electromagnetic radiation. In at least some cases, surface plasmons enable dramatic improvements in the performance of conventional photonic components such as modulators and switches. Nanotechnology may be loosely defined as a branch of engineering that deals with things that are smaller than nm, especially involving the construction of structures from the bottom up by manipulating individual atoms and molecules. For example, carbon atoms can be arranged to make either coal or diamond, among other materials. Photonics is the science and technology of generating and controlling light particles photons and, in particular, of using light to carry information. It therefore deals with photons largely in the same manner that electronics deals with electrons. Photons are unmatched in speed nothing beats the speed of light and in their potential for data capacity switching light on and off is easy because photons have no mass. The modern communications systems managing huge amounts of data and Internet traffic thus are based on glass fibers transmitting light signals worldwide. Information processing at ever-increasing rates is evolving toward the use of nanophotonics. This involves not only very small photonic circuits and chips, but also new ways of sculpting the flow of light with nano-structures and nanoparticles that exhibit fascinating optical properties unseen in the macroscopic world. Communicating at the nanoscale using light is a challenge. For most materials, interactions between light and matter are reduced when the size of the structures is much smaller than the wavelength of the light. There is a fundamental incompatibility between propagating light e. However, metals that support the surface collective oscillations of free electrons called surface plasmons can concentrate electromagnetic fields on the nanoscale while enhancing local field strengths by several orders of magnitude. Nanostructures using surface plasmons have been extensively investigated during the past decade. They exhibit a variety of novel effects, including extraordinary light transmission, giant field enhancement and surface plasmon waveguiding. Electromagnetic radiation in the form of waveguide modes propagating in and confined to the core by virtue of total internal reflection can be controlled with externally applied electrical signals through electro-, magneto- and thermo-optic effects. The controlling electrodes placed near the waveguides result in radiation loss by absorption and scattering. Increasing the separation between the electrodes and waveguide can minimize this loss, but that also decreases the useful effects. This makes the positioning of electrodes in conventional waveguide devices a challenging design problem. Ideally, one would like to send the light and electrical signals along the same channel, facilitating information transfer from electronic to optical circuits. It turns out that thin metal stripes surrounded by a dielectric can be employed for both guiding radiation in the form of surface plasmon modes and for controlling its propagation; that is, modulation and switching. The surface plasmon mode field distribution near a thin metal film embedded in a dielectric is shown with the orientation of the dominant electric field component a. A surface plasmon stripe waveguide was fabricated by sandwiching gold stripes between layers of polymer b. An optical microscope image reveals the intensity distribution of thefundamental surface plasmon mode at the output facet of a waveguide stripe excited at 1. Judging from the lateral mode distribution, such a surface plasmon stripe guide is similar to a conventional dielectric buried waveguide. It therefore is natural to recycle design ideas that are well-known in integrated optics and to apply them to surface-plasmon-based photonic components. Indeed, sharp and gradual adiabatic bends, Y-splitters, multimode interference junctions and directional couplers using surface plasmon stripe waveguides were demonstrated with overall performance similar to that of the best analogues from integrated optics. This has enabled the fabrication of devices such as a thermo-optic Mach-Zehnder interferometric modulator, a directional-coupler switch and an in-line extinction modulator, all of which use surface plasmon waveguiding along thin gold stripes embedded in a polymer and heated by electrical signal currents. The radiation is guided along the metal stripe, with the field reaching its maximum value at the metal surface. In general, polymers exhibit highly efficient thermo-optic effects. The generic operating principle of the Mach-Zehnder interferometric modulator is as follows: In the absence of a control signal, an input wave is split equally into two waves traveling along identical arms of the interferometer, which are recombined to produce an output wave. Ideally, the two waves meeting in the output junction are identical in phase and amplitude. If the waves are exactly out of phase, they cancel each other, and the result is zero output. Schematics illustrate the structure of a Mach-Zehnder interferometric modulator a , directional-coupler switch b and in-line extinction modulator c. In the thermo-optic Mach-Zehnder interferometric modulator Figure 2a , the surface plasmon propagation constant is changed in the heated arm, resulting in a phase difference between two surface plasmon modes that interfere in the output Y-junction. The active waveguide length was 5. The driving power of the Mach-Zehnder interferometric modulator is considerably lower than that of a conventional, photonic device. The inset shows the temporal response of the modulator, measured with an offset of 2 V and a peak-to-peak voltage of 3. The achieved driving power is considerably lower than that of conventional photonic thermo-optic Mach-Zehnder interferometric modulators because the control electrode is positioned exactly at the maximum of the long-range surface plasmon mode field, inducing the maximum change in its effective index. This estimate is close to the measured value and indicates that using polymers with larger thermo-optic coefficients can decrease the driving power even further. In a generic directional-coupler switch, two waveguides are in proximity over a portion of their length. As an input wave travels in one of the waveguides, it gradually tunnels into the other, which is identical in the absence of a control signal to the input side. The efficiency of this tunneling deteriorates if the two waveguides become different in the sense that the corresponding modes travel with different speeds. By controlling the propagation constant in one of the waveguides, one can completely stop the tunneling process. Hence, a directional-coupler switch can be used to efficiently switch radiation between the two waveguides at the output. Proper operation of a directional-coupler switch Figure 2b requires that the radiation injected into one arm at the input efficiently tunnel into another arm in the interaction region where the arms are close enough for complete power transfer. Heating one of the arms induces a phase mismatch between the surface plasmon modes propagating in the coupled waveguides and thereby destroys efficient tunneling. The corresponding directional-coupler switch was 15 mm long, and the best performance was obtained when the waveguide carrying the coupled radiation was heated: Optical switch This switching behavior implies that the directional-coupler switch can be used as a digital optical switch, an attractive component for space-division switching in broadband photonic networks. The electrode length can be optimized, considerably reducing the switching power. This suggests a simple configuration for intensity modulation Fig. Effectively, the heating destroys waveguiding and increases the radiation extinction in transmission, yielding an in-line extinction modulator. Fabricated in-line extinction modulators were 10 mm long with an active waveguide and electrode length of 1 mm. This value can be regarded as reasonably close to the estimate because the latter does not refer to the extinction level, which depends on the surface plasmon mode divergence in the heated region. The in-line extinction modulator achieved an output power extinction ratio of 10 dB for applied electrical power of approximately 23 mW. An extinction ratio of more than 25 dB for 50 mW is feasible. The insets showmicroscope images of the intensity distributions at the output facet of themodulator for different values of applied electrical power. A similar extinction ratio is expected even for a considerably shorter in-line extinction modulator still having a 1-mm-long electrode , which suggests a method of reducing the propagation and, thereby, the total insertion loss. Finally, it should be emphasized that in-line extinction modulator operation depends weakly on wavelength, implying that the same modulator can be used in a broad range of wavelengths with proper adjustments to the applied electrical power. The dynamic components discussed here represent the first use of the unique features inherent in surface plasmons that enable the same metal stripe to guide and efficiently control optical radiation. Moreover, the fact that surface plasmons are partially absorbed as they propagate along a metal stripe can be turned around and exploited to monitor the surface plasmon power. Furthermore, the same design principles can be applied to configurations such as Yand X-junction-based digital optical switches and variable optical attenuators. The principles also can be modified to employ other control effects, including electro-optic ones. And it should be noted that surface plasmon components are based on true planar-processing technology, which considerably simplifies the development, large-scale integration and fabrication of photonic devices. However, these components, although novel in design, are similar to their photonic analogues and relatively straightforward in operation. Many surface-plasmon-based structures, in contrast, are unique with regard to the principles of their operation and performance. Next month , we will discuss this sort of plasmonic structure for nanophotonics, including biomolecular sensors and negative-index materials. Meet the authors Sergey I. Bozhevolnyi is a professor in the department of physics and nanotechnology at Aalborg Universitet in Denmark; e-mail: Surface plasmon subwavelength optics. Surface plasmon polariton based modulators and switches operating at telecom wavelengths. In-line extinction modulator based on long-range surface plasmon polaritons. Nikolajsen et al Feb. Polymer-based surface-plasmon-polariton stripe waveguides at telecommunications wavelengths. Boltasseva et al January Integrated optical components utilizing long-range surface plasmon polaritons. Integrated power monitor for long-range surface plasmon polaritons. Understanding Surface Plasmons Light is composed of optical waves with a spatial period the wavelength that is determined by the refractive index of the medium through which the light is traveling. Surface plasmons propagate along this interface, feeling the effects of both media. A schematic representation of a surface plasmon field distribution shows the orientation of the electric blue and magnetic purple fields a. Various scenarios exist to couple long-wavelength light to short-wavelength surface plasmons that can interact efficiently with nanostructures b. In turn, a surface plasmon wave can be excited with a typical light source by using a nanostructure such as a nanoparticle placed at the metal surface.

Chapter 2 : Nanophotonics with Surface Plasmons -- Part I | Features | Jan | Photonics Spectra

Nanophotonics with Surface Plasmons - Part II Photonics Spectra Feb The evolving technology of plasmonic nanophotonics seeks to combine the capabilities of nanotechnology and photonics.

Thanks to recent fabrication advances, nanophotonic applications have been growing in number and diversity. The anticipated attainment of 16nm lithography resolution by would further advance the field by improving system integration. The increased resolution would lead to fabrication methods that are reliable, scalable, power-efficient, and cost-effective. Nanoscale component integration would be feasible, both from the top down e. In recent efforts to develop nanophotonic waveguides, attention has focused on optical modes that are concentrated at the interface between metallic and dielectric materials. This interest was sparked by the discovery that the modes exhibit enhanced light transmission through nanohole arrays and regions of nanoscale surface corrugations. These characteristics could lead to photonic devices smaller than optical refraction technologies can currently achieve. They might also help bridge the gaps between photonics, biochemical sensing, and CMOS-based electronics technologies. Many potential SPP-based information technology applications will require a complete understanding of in-plane SPP pulse propagation, but previous studies have generally focused on steady-state behavior. To address this challenge, we developed a way to excite and visualize the propagating pulse. In our experiments, 6,7 we used a 2D nanohole array to couple the optical field into a metallic film on a dielectric substrate. To better understand the excitation and propagation process of the SPP modes, we constructed a laser-illuminated imaging apparatus 6 shown schematically in Figure 1 a. A polarizer-analyzer pair is used to control the polarization state of the excitation field and the field in the image plane. In contrast to typical far-field measurements, this apparatus images the metal film onto a CCD camera. The spectra are dominated by asymmetric, Fano-type line shapes at the various SPP excitation conditions. The transmitted field has two components: The interference between these two components yields the amplitude extremes seem in Figure 1 b. The outlines of these major features of the dispersion map are well described by the relation: SPP modes are labeled in terms of the lattice momentum needed to excite a mode, which travels along the metal surface in the corresponding direction. We recently applied our findings to construct a high-spectral-resolution surface plasmon-resonance SPR sensor that operates at and near normal incidence, and which facilitates high spatial-resolution imaging. The array fine control achieved about nm for the hole diameter. Measurements were made using the setup shown schematically in Figure 2 a. When the polarizer and analyzer are parallel, we get Fano-type transmission lines, as in Figure 1 b , indicating a combination of scattering and resonance. When the polarizers are orthogonal, the background radiation is suppressed, and there is only a pure resonance Lorentzian transmission line. This line width is narrower in both frequency and phase, and thus can be used to effectively monitor changes in refractive index. The salt concentration could have also been interrogated using wavelength changes. Data from arrays with different periods, a, were combined for the composite intensity image. The stitching frequencies appear as horizontal black lines, and data are replicated at negative wavenumbers for viewing. The input and output polarization states of a tunable laser are controlled, providing variable spectral or angular Fano-type profiles. A microfludic channel transports the analyte fluid to the surface of the sensing area, and can tune the SPP resonance frequency by controlling the refractive index at the metal-dielectric interface. Shown in the upper left are scanning electron microscope images of a representative sample. The black line is a linear fit to the log-log data. Resonant phase peak shift. This heightened sensitivity can be used to monitor chemical reactions of various types by attaching molecules to the surface and supplying probe molecules in the analyte fluid. We estimate the potential of this system of order RIU under optimal conditions, with a nonabsorbing over-layer. In the future, the SPP combined with optofluidics will have a significant impact on applications such as nanoscale spectroscopy, tomography and metrology, live cell dynamics, sensing, and hyper-spectral imaging of biological species. The investigation of opto-plasmonic fields and learning to control them on a nanoscale have the potential to lead to new tools that can advance cell biology and medicine. His research interests include nanophotonics, near-field optics, plasmonics, information processing with femtosecond pulses, quantum information processing, diffractive and nonlinear optics, adaptive optics, and multidimensional imaging. Fainman co-chaired a conference on optofluidics in

Chapter 3 : Nanophotonics - Wikipedia

Understanding Surface Plasmons Light is composed of optical waves with a spatial period (the wavelength) that is determined by the refractive index of the medium through which the light is traveling. Surface plasmons are electromagnetic excitations that are bound to a metal/dielectric interface, and they represent optical waves coupled to free.

The evolving technology of plasmonic nanophotonics seeks to combine the capabilities of nanotechnology and photonics. Shalaev, Purdue University, and Sergey I. During the Middle Ages, for example, infusions of colloidal metal particles in glass produced wondrously brilliant colors for cathedral windows. The colors were due to the excitation of plasmon oscillation modes in the metal particles, creating absorption bands and producing unique colors in the transmitted light. As discussed last month in the first part of this feature, plasmonic materials are structures that support surface plasmon oscillation modes. In a metal, the conduction electrons are essentially free to move, with little interaction from their respective nuclei because of Coulomb shielding effects. The electric field of an incoming lightwave induces polarization of the conduction electrons with respect to the much heavier ionic cores of the metal atoms. At the surface of the metal, a net charge is produced. The net charge difference on the surface then acts as a restoring force for the polarization. As a result, the electrons oscillate coherently. If the frequency of the incident electromagnetic field is resonant with the coherent electron motion, a strong absorption in the spectrum is observed see below. Noble metals such as copper, silver and gold historically have dominated the studies of plasmon effects because their resonances are the strongest and occur in the visible part of the electromagnetic spectrum. Many structures support plasmon oscillations, however. Small metal spheres, such as those used in stained-glass windows, are one example. Sensing with plasmons Surface plasmons can be employed for developing efficient biosensors. Biosensing, the detection and analysis of biomolecules such as proteins, has become an area of great interest for research as well as for applications such as environmental testing, national security, and process engineering and control. In brief, a typical setup consists of a metal layer sandwiched between a high dielectric medium â€” e. Light is incident from the higher dielectric medium onto the metal surface. Surface plasmon resonance can be used to sense antibody-antigen binding by changes in the reflected intensity from the flow channel. Hence, the intensity of the reflected light is smaller at the resonance because a portion of the incident energy is used for surface plasmon excitation. When the resonance condition is destroyed, a measurable increase in the reflected intensity is generated Figure 1, right. Even a very small change in the dielectric permittivity results in a detectable shift of the resonance condition. Therefore, the surface plasmon resonance technique enables the detection of minuscule changes in the flow channel. For example, it is sensitive enough to detect antibody-antigen Ab-Ag binding events, which are of great importance for performing bioassays, detecting disease biomarkers, and developing drugs and for use in many other biomedical applications. Localized surface plasmon resonance also is highly sensitive to variations in the environment and thus can be used for the detection of antibody-antigen binding Figure 2. The frequency of the localized surface plasmon resonance strongly depends on the environment. There is no dependence on the photon momentum because the structure is much smaller than the wavelength. Localized surface plasmon resonance also may be used to detect antibody-antigen binding. The frequency is highly dependent on the environment, and a localized surface plasmon resonance structure can experience a resonance shift of approximately 20 nm in response to antibody-antigen binding. Another important nanostructure that employs the localized surface plasmon resonance effect and can be used in many sensing applications is a nanoshell. Nanoshells are nanoparticles that consist of a dielectric core surrounded by a metal shell, typically gold. The resonance functionality mimics that of metal nanospheroids. The localized surface plasmon resonance in nanoshells depends on the ratio of the dielectric core radius to the metal coating radius. It thus is an engineered parameter rather than the single resonance obtained from simple gold or silver nanoparticles. This can offer application benefits. For example, nanoshells designed to absorb at wavelengths near nm could be used for in vivo techniques and controlled externally because tissue is relatively transparent at nm. Different from surface plasmon resonance or localized surface plasmon resonance, Raman scattering sensing techniques can not only detect the presence of a biomolecular analyte, but also provide a great deal of information on what material is being detected. Surface plasmons result in enhanced local fields, so they can dramatically enhance the Raman signal, which depends linearly on the local field intensity. We mention here only some recent and particularly efficient and sensitive surface-enhanced Raman scattering substrates. They include nanoshells developed by Naomi J. Field-emission scanning electron microscope images of two substrates from one batch illustrate a nm silver film, with a transmission at nm of 0. Images were collected eight weeks after fabrication; proteins were deposited one week after fabrication. The adaptive silver films are fabricated at a certain range of deposition parameters, and they allow the fine rearrangement of their local structure under protein deposition Figure 3. Such a substrate enhances surface-enhanced Raman scattering and makes possible protein sensing at a monolayer protein surface density. The vacuum-evaporated films also allow label-free surface-enhanced Raman scattering detection of Ab-Ag binding. Negative refraction The photon is the ultimate messenger, packaging data in a signal of zero mass and unmatched speed. The refractive index is one of the most fundamental material characteristics influencing photons and their propagation. It provides the factor by which the phase velocity of light decreases in a material compared with vacuum conditions. Of particular recent interest to researchers are materials that have a negative refractive index; that is, the phase velocity is directed against the flow of energy. There are no known naturally occurring examples of such materials. Metamaterials can open avenues to achieving unprecedented physical properties and functionalitiesthat are unattainable with natural materials. Because they bring the refractive index into a new domain of exploration, they promise to create entirely novel prospects for manipulating light, resulting in a revolutionary impact on optical technologies. Proof-of-principle experiments have shown that metamaterials can possess negative indices at microwave wavelengths. Pendry of Imperial College London predicted that they could act as superlenses, enabling imaging resolutions that are limited not by wavelength but by material quality. The near-field version of the superlens already has been reported. Recent experiments show that a magnetic response and negative permeability can be accomplished in the terahertz spectral ranges. The experimental realization of a negative refractive index for metamaterials in the optical range at 1. The first experimental observations of negative refractive indices at optical frequencies were based on earlier theoretical predictions. Optical negative-index material structures may be based on paired nanorods, as displayed in a schematic a and in an electron-beam fabricated sample b. The Shalaev group demonstrated an index of refraction of The twin nanowires form an open current loop with a resonant current, analogous to a telegraph line. Recent progress in the fabrication and understanding of negative-index materials, followed by demonstrations of negative refraction first in the microwave and then in the optical ranges, provides the enabling science and technology for rapid advancements in this emerging area. There is an undeniable need for novel devices with the unique characteristics that can be provided by materials with negative indices. However, the understanding of the interaction of light with such materials is still in its infancy. Also, available optical negative-index materials are prone to losses. Thus, full integration of light with these unique materials requires fundamental advances in this research area. In summary, the power of light is driving the photonics revolution, and the technologies formerly based on electronics increasingly enlist light to communicate and provide intelligent control. Shalaev acknowledges help from Mark D. Thoreson in preparing this article. Meet the authors Vladimir M. Bozhevolnyi is a professor in the department of physics and nanotechnology at Aalborg Universitet in Denmark; e-mail: Surface plasmon resonance sensors: Raschke et al July Biomolecular recognition based on single gold nanoparticle light scattering. Prodan et al Oct. A hybridization model for the plasmon response of complex nanostructures. Van Duyne July Dichroic optical properties of extended nanostructures fabricated using angle-resolved nanosphere lithography. Drachev et al Aug. Adaptive silver films for detection of antibody-antigen binding. Schultz April 6, Experimental verification of a negative index of refraction. Negative refraction makes a perfect lens. Fang et al April 22, Sub-diffraction-limited optical imaging with a silver superlens. Linden et al Nov. Magnetic response of metamaterials at terahertz. Grigorenko et al Nov. Nanofabricated media with negative permeability at visible frequencies. Shalaev et al Dec. Negative index of refraction in optical metamaterials. Zhang et al Sept. Experimental demonstration of near-infrared negative-index materials. Plasmon modes in metal nanowires and left-handed materials. Berrier et al Aug. Negative refraction at infrared wavelengths in a two-dimensional photonic crystal. Schonbrun et al June Negative refraction in a Si-polymer photonic crystal membrane. Building Nanoantennae Localized surface plasmons represent collective oscillations of free electrons in small metal nanoparticles, such as nanospheres or other nanoparticles and their groups.

Chapter 4 : Lab News - Nanophotonics and Plasmonics Lab

Nanophotonics with Surface Plasmons and millions of other books are available for Amazon Kindle. Learn more Enter your mobile number or email address below and we'll send you a link to download the free Kindle App.

With its potential to exponentially increase computing power, quantum computing opens up possibilities to carry out calculations that ordinary computers could not finish in the lifetime of the universe, whereas optical communications based on quantum cryptography become completely secure. At the same time, the emergence of Big Data and the ever-increasing demands of miniaturization and energy-saving technologies bring about additional fundamental problems and technological challenges to be addressed in scientific disciplines dealing with light-matter interactions. In this context, quantum plasmonics represents one of the most promising and fundamental research directions and, indeed, the only one that enables the ultimate miniaturization of photonic components for quantum optics when being taken to extreme limits in light-matter interactions. In this context, quantum plasmonics represents one of the most promising and fundamental research directions [2], [3] and, indeed, the only one that enables the ultimate miniaturization of photonic components for quantum optics when being taken to extreme limits in light-matter interactions Figure 1. Whereas plasmon phenomena are inherently of quantum nature, surface plasmons SPs [4] have, for decades, been successfully explored with a mindset of classical electrodynamics [5] bottom left corner. However, fundamental problems found in all corners of this schematic chart Figure 1 increase exponentially their complexity when coming to experience also fundamental size limitations posed by the very nature of both light and matter, both consisting of quanta and thereby being discrete. Below, we discuss some intriguing aspects of the different regimes outlined in Figure 1. Quantum aspects of plasmonics exhibit both in the quantum nonlocal response of matter and in the quantized light fields. In the main text, we outline three challenges associated with this. Intriguing and classically unexpected experimental observations include frequency blue-shifts of plasmon resonances in few-nanometer silver nanoparticles [8], [9] and gold plasmonic gap structures [10] as well as gap-dependent broadening and onset of charge-transfer plasmons in dimers and gap structures with subnanometer gaps [11], [12], [13]. Theoretical explanations range from hydrodynamic nonlocal response [14], [15] to ab initio quantum mechanics [16], [17], accounting for quantum effects such as quantum pressure waves, Landau damping, quantum spill-out, and tunneling. Here, the quantumness is in the nonclassical states of the electromagnetic field or in the quantum properties of the light emitters [20], [21]. As an appetizer from this almost virgin territory of quantum plasmonics, we here mention the recent exploration of single-molecule strong coupling dynamics in subnanometer plasmonic gap cavities [22]. Many crucial issues in modern plasmonics revolve around the fact that the most exciting and unique feature of plasmonic modes, viz. The fundamental problem is then to understand to what extent this unique feature, enabling both ultimate miniaturization [24] and ultra-strong coupling to quantum emitters QE [25], should be exercised before the inevitable energy loss destroys the outcome of its exercise. Enormous challenges emerge already on the way to proper formulation of the associated problems, as the whole well-developed macroscopic treatment of light-matter interactions breaks down and no longer works on the nanoscale, requiring nonlocal and quantum effects to be taken into account. The whole set of fundamental problems associated with extreme plasmonics can be factorized into several tradeoffs representing conflicting tendencies that are being enormously enhanced when reaching extreme limits. A careful analysis and assessment of these tradeoffs is indispensable for the accurate mapping of the field boundaries and potential developments. In this context, the exploration of fundamental limits in light-matter interactions can be categorized into several major research challenges that are all related to the aforementioned key issues. Alternatively, localized surface-plasmon LSP excitations enable extreme light confinement down to nanometer-scale , thereby providing unique possibilities for SE enhancement [2]. It should be noted that the most promising results ultrafast SE emission have been obtained with special SP resonators, viz. In this case, the Purcell factor is determined by the ratio between the waveguide mode group index and the mode area i. Contrary to that, various WSP modes, including the gap and channel SP modes [27], can be confined practically at any wavelength within extremely small cross-sections, thereby increasing the QE-WSP coupling efficiency [28]. At the same time, however, the loss-related problems would also become significant. In fact, one should simultaneously maximize the Purcell factor, the coupling to propagating SP modes rather than to lossy SPs , and the normalized SP propagation length [19]. A novel issue in this context is the problem of unidirectional and efficient SE into WSP modes [29], as one would ideally couple all emitted photons into WSP quanta propagating in the same direction. Another unique feature of SP-based waveguides Ch3 is related to the possibility of seamless interfacing of electronic and photonic circuits by employing the same metal circuitry for both guiding the optical radiation and transmitting the electrical signals that control the guidance [30]. The latter implies that metal electrodes used for radiation control are located at the maximum of the WSP mode intensity reached at the metal-dielectric interface , maximizing the controlling efficiency and thus ensuring considerably lower power requirements. This feature opens unique perspectives for substantial reductions in sizes and energy of SP-based photonic components and circuits while extending the operation bandwidth [31]. It also allows one for the realization of conceptually new functionalities and exploitation of new materials with fascinating properties, such as single-crystalline gold films [32] or graphene [33], as demonstrated, for example, by realizing hybrid SP-graphene waveguide modulators [34]. The degree of WSP modulation can be enhanced by squeezing the WSP mode area and thereby increasing the slowdown factor. The associated increase in the WSP absorption has to be carefully investigated and analyzed to take advantage of the enormous potential of the aforementioned unique WSP characteristics. Proper analysis requires the further development of the theoretical models tailored suitably for dealing with nanostructured light-matter interactions. Spinoff directions Investigations of the underlying physics and fundamental limitations associated with LSP excitations would be greatly beneficial for the whole field of flat optics based on phase and amplitude-gradient metasurfaces [35], allowing one to mould the radiation with an unprecedented control over its polarization and propagation characteristics as well as to produce surface coloration at nanoscale [36]. In the field of sustainable energy sources, LSP-induced resonance energy transfer becomes increasingly important for solar energy conversion [37]. Moreover, recent groundbreaking discoveries emphasize that even inevitable light absorption in plasmonics can be turned into gain within various topics: Finally, mastering unique plasmonic features associated with the excitation of both LSP and WSP would most certainly provide additional possibilities for pairing photons with phonons in quantum optomechanics [39]. It is thus clear that studies related to the above objectives would have major consequences and implications to many subfields of modern nanoscience and emerging quantum technologies [40], including radiation-lifetime engineering, plasmon-enhanced chemistry, single-molecule sensing, quantum microscopy, quantum optics, and optomechanics in general and single-photon sources in particular. Europe plans giant billion-euro quantum technologies project. Springer International Publishing, Berlin, Springer, New York, Plasmonics beyond the diffraction limit. Nonlocal optical response in metallic nanostructures. J Phys Condens Matter ; Quantum plasmon resonances of individual metallic nanoparticles. Multipole plasmons and their disappearance in few-nanometre silver nanoparticles. Probing the ultimate limits of plasmonic enhancement. Revealing the quantum regime in tunnelling plasmonics. Controlling subnanometer gaps in plasmonic dimers using graphene. Quantum plasmon resonances controlled by molecular tunnel junctions. A generalized non-local optical response theory for plasmonic nanostructures. Resonance shifts and spill-out effects in self-consistent hydrodynamic nanoplasmonics. Quantum mechanical effects in plasmonic structures with subnanometre gaps. Generation of single optical plasmons in metallic nanowires coupled toquantum dots. Coupling of individual quantum emitters to channel plasmons. Quantum optics with surface plasmons. Phys Rev Lett ; Coupling single emitters to quantum plasmonic circuits. Single-molecule strong coupling at room temperature in plasmonic nanocavities. How to deal with the loss in plasmonics and metamaterials. Nanofocusing of electromagnetic radiation. Modified spontaneous emission in nanophotonic structures. Ultrafast spontaneous emission source using plasmonic nanoantennas. Gap and channeled plasmons in tapered grooves: I Quantum plasmonic circuits. Phys Today ;61 5: All-plasmonic Machâ€"Zehnder modulator enabling optical high-speed communication at the microscale. Silicaâ€"gold bilayer-based transfer of focused ion beam-fabricated nanostructures. Hybrid graphene plasmonic waveguide modulators. Planar Photonics with Metasurfaces. Nat

Rev Mater ;2: Plasmon-induced resonance energy transfer for solar energy conversion. Plasmonics-turning loss into gain the optical losses associated with plasmonic materials could be used in applications. Non-classical correlations between single photons and phonons from a mechanical oscillator.

Chapter 5 : Surface plasmon - Wikipedia

NANOPHOTONICS WITH SURFACE PLASMONS Edited by V.M. SHALAEV Purdue University School of Electrical & Computer Engineering Indiana, USA S. KAWATA Department of Applied Physics.

A more comprehensive comparison of a wide range of plasmonic metals red circles , metal alloys pink hexagons , doped semiconductors blue stars and SPhP materials green squares are provided in Figure 4 B. For noble-metal plasmonic structures, the electrostatic resonances tend to occur in the visible and near-IR, with Q in the 20â€”40 range, depending on the particular data set and material, corresponding to modal lifetimes on the order of 10 fs. As a result, no improvement in the Q over the metallic case is expected. However, recent work within n-type CdO demonstrates Q on the order of 40, similar to plasmonic metallic systems, while offering resonances in the mid-IR, thus providing a promising alternative plasmonic material [33]. Figure 4 A calculated Q-factor [eq. Table 1 Calculated wavelengths and corresponding localized, propagating and ENZ FOMs for plasmonic metals and doped semiconductors discussed in the text. Table 2 TO and LO phonon frequencies reported in the specific reference, high and low-frequency permittivity, best reported damping constants and calculated wavelengths and corresponding localized, propagating and ENZ FOMs for phonon polariton materials discussed in the text. For SPhP materials such as SiC, the damping time is increased to several picoseconds, while the operating frequency is reduced by an order of magnitude. The application of Eq. Note that these values are over an order of magnitude higher than in noble metals. The maximum attainable Q is limited by the intrinsic damping due to phonon-phonon scattering, which is discussed in Section 4. In real structures, the imaginary part of the permittivity and, hence, the Q are also reduced by surface roughness in both plasmon-based and phonon-based structures. In addition, the Q of nanostructures from SPhP material may be affected by free carriers via the Drude term given in Eq 2. Table 3 Isotope averaged atomic masses and reduced effective charges Z are given for a variety of materials. The potential of localized SPhP resonant particles has been demonstrated in several works, starting with the first observations which occurred in the studies of interstellar SiC nanoparticles []. The first efforts focusing on the use of SPhP materials for realizing localized resonances took place in with the seminal works of Hillenbrand et al. As shown in Figure 5 A, the 4H-SiC exhibits a dramatic enhancement in the scattering amplitude of the incident optical fields at the resonance frequency associated with the image charge of the SNOM tip in comparison to the surrounding gold. The high absorption cross-section of such sub-wavelength SPhP resonators is a driving force for many potential applications, including mid-IR narrow-band thermal emission sources with tailored spectral characteristics. This has led to many subsequent efforts, including the work of Schuller et al. B Angle dependence of the reflectivity of SiC gratings within the Reststrahlen band demonstrating the ultranarrow and polarization sensitive SPhP response. AFM micrograph of SiC grating. Reproduced with permission from Ref. More recently, localized SPhP modes have again become an exciting area of research. The first effort, reported by our group [23] showed that lithographic fabrication could be used to design SPhP resonators with a priori defined resonant frequencies, accomplished through the control and design of nanostructure geometry, size and periodicity Figure 6 A. Efforts by Wang et al. Such effects enable the investigation of Fano and other interference phenomena and the associated dark modes which typically exhibit exceptionally narrow linewidths []. Such large enhancements demonstrate the potential for such systems to enhance local emitters or IR-active vibrational modes for molecular spectroscopy. However, this behavior has not yet been explored in any depth, so comparisons of such coupled structures are premature. SEM micrograph of representative nanopillar array. Recently, SPhP modes within hexagonal boron nitride hBN demonstrated another possibility for polar dielectrics unavailable in plasmonic systems: By definition a hyperbolic material is one in which the real permittivities along the two orthogonal principal axes have opposite signs, i. Nanostructures of hBN on quartz were shown to exhibit similarly high Q-factors 60â€” as those observed in SiC systems, except they were observed within two distinct spectral bands corresponding to the upper 6. Furthermore, the resonances implied the presence of a novel type of optical mode, the hyperbolic polariton [53]. Such hyperbolic polaritons offer sub-diffraction confinement, with the mode confined within the volume of the material, rather than on the surface. Such efforts illustrate the immense potential of SPhP materials and can provide the building blocks for a wide array of potential metamaterial and nanophotonic applications, as will be discussed in Section 5. Numerous potential geometries for propagating polariton modes can be envisioned. While it is often said that metal-based SPPs are very weakly confined at the wavelengths where SPhP modes are supported, the confinement can be arbitrarily strong at any wavelength for the so-called MIM metal-insulator-metal waveguide with very thin insulator layers and various geometries. From this, it is straightforward to show that:

Chapter 6 : Nanophotonics: Manipulating Light with Plasmons - CRC Press Book

Nanostructured metals which support surface plasmon modes can concentrate electromagnetic (EM) fields to a small fraction of a wavelength while enhancing local field strengths by several orders of magnitude.

Background[edit] Normal optical components, like lenses and microscopes, generally cannot normally focus light to nanometer deep subwavelength scales, because of the diffraction limit Rayleigh criterion. Nevertheless, it is possible to squeeze light into a nanometer scale using other techniques like, for example, surface plasmons , localized surface plasmons around nanoscale metal objects, and the nanoscale apertures and nanoscale sharp tips used in near-field scanning optical microscopy NSOM and photoassisted scanning tunnelling microscopy. A few of these goals are summarized below. Optoelectronics and microelectronics[edit] If light can be squeezed into a small volume, it can be absorbed and detected by a small detector. Small photodetectors tend to have a variety of desirable properties including low noise, high speed, and low voltage and power. Very small lasers require subwavelength optical cavities. An example is spasers , the surface plasmon version of lasers. Integrated circuits are made using photolithography , i. In order to make very small transistors, the light needs to be focused into extremely sharp images. It requires a laser to heat a tiny, subwavelength area of the magnetic material before writing data. The magnetic write-head would have metal optical components to concentrate light at the right location. Miniaturization in optoelectronics , for example the miniaturization of transistors in integrated circuits , has improved their speed and cost. However, optoelectronic circuits can only be miniaturized if the optical components are shrunk along with the electronic components. This is relevant for on-chip optical communication i. Researchers have investigated a variety of nanophotonic techniques to intensify light in the optimal locations within a solar cell. If a given amount of light energy is squeezed into a smaller and smaller volume "hot-spot" , the intensity in the hot-spot gets larger and larger. This is especially helpful in nonlinear optics ; an example is surface enhanced Raman scattering. It also allows sensitive spectroscopy measurements of even single molecules located in the hot-spot, unlike traditional spectroscopy methods which take an average over millions or billions of molecules. Near-field scanning optical microscope NSOM or SNOM is a quite different nanophotonic technique that accomplishes the same goal of taking images with resolution far smaller than the wavelength. It involves raster-scanning a very sharp tip or very small aperture over the surface to be imaged. For example, dual polarization interferometry has picometer resolution in the vertical plane above the waveguide surface.

DOWNLOAD PDF NANOPHOTONICS WITH SURFACE PLASMONS

Chapter 7 : Nanophotonics: sensing with surface plasmon polaritons | SPIE Homepage: SPIE

Chapters were written by the leaders in the field of plasmonics A solid background is given to each topic State-of-the-art in the field Overview of all areas in the field that have shown major developments in the last few years A rapidly developing field with major applications in electronics.

Lab News in March 29, The topic of his thesis is transparent THz electrodes using structured gold films. Journal of Photonics Research , which Prof. Guo serves as an Associate Editor, achieved an impact factor of 4. He also visited Moscow after the meeting. Lab News in September 19, He also served as a co-chair of the best student paper award session for optics and photonics in the conference. Guo was granted a U. Guo serves as an Associate Editor, received its first impact factor of 3. Lab News in October 25, He also presented a paper in the meeting. Guo was invited to have a dinner meeting with his former students and alumni of UAH working in the silicon valley. He was very impressed and pleased by the roles of his former students in the photonic industry in silicon valley. Hong also presented a paper on optical antennas in the meeting. He presented a paper and chaired a session in the conference. He organized and chaired a session on ultra-thin structure plasmonic photonics and presented three papers in the PIERS conference. Sadra Mirshafieyan received the second place award for his poster presentation in the Ph. Laser Focus World Magazine is a popular optical and photonics technology magazine that reports new technologies with significant potential impact. Lab News in December 18, David Brady at Duke University and also visited Prof. Guo was invited to serve in a two-day NSF program review panel. He took a tour of the Martin Luther King, Jr. Memorial after the NSF panel. Guo attended the meeting and met with Prof. Robert Magnusson and Prof. He presented his work on plasmonic gap-mode resonance absorbers in the conference. Boyang was hired to work for OmniVision Technologies in California. Former American astronaut, Dr. Jan Davis, visited our lab. He also visited a research group of Prof. George Barbastathis at the National University of Singapore. After the lecture, Dr. Stahl had a tour of our lab and had good conversations with students. Hong Guo received the third place award for his poster presentation in the Ph.

Chapter 8 : Low-loss, infrared and terahertz nanophotonics using surface phonon polaritons : Nanophotoni

1. SURFACE PLASMON NANOPHOTONICS 3 Stephen Cunningham and his colleagues introduce the term surface-plasmon-polariton (SPP) in Another major discovery in the area of metal optics occurs in that same.

Chapter 9 : Issue 11 () â€“ Nanophotonics

Nanophotonics: Manipulating Light with Plasmons starts with the general physics of surface plasmons and a brief introduction to the most prominent research topics, followed by a discussion of computational techniques for light scattering by small particles. Then, a few special topics are highlighted, including surfaceenhanced Raman scattering.