DESIGN OF OPTICAL LINK FOR OPTICAL NANO ANTENNAS

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ABSTRACT

The optical complement of microwave antennas, optical nano-antennas are important devices for converting propagating waves into confined/enhanced fields at nano scale. Their applications in areas with critical needs, e.g., in sensing, imaging, energy harvesting, and disease cure and prevention, have brought revolutionary improvements. This dissertation investigates important uniqueness of these plasmonic resonators through optical and electron-beam excitation using nanostructures defined by lithography as well as a recently developed direct metal patterning technique. The important challenges in optical antenna research consist of both fundamental understanding of the essential physics as well as issues related to fabrication of low cost, high throughput nanostructures away from the diffraction limit. Finally, I discuss the part of CL in characterizing metal nano-disks which illustrate multiple modes and have sizes analogous to their resonance wavelengths. CL provides a unique opportunity to map the superior fields from interference of surface plasmons sustained on the disks. The sympathetic of these modes is critical for the application of resonant metal cavities for the next generation of optical devices including nano-lasers.

KEYWORDS- Optical nano-antennas, Energy harvesting, Electron –beam, Fabrication, Low cost, Nano-disk, Plasmonic, Nano-laser.

I.INTRODUCTION

In the past few years, an stimulating development in nano-optical research has position in with the recognition that metallic nano particles with their plasmon resonances may be used in a approach very analogous to the way electrical engineers of the twentieth century have developed radio-frequency (RF) antennas. This introduces the idea of optical nano-antennas. Following many of the same rules that relate to RF antenna design, also the properties of optical nano-antennas can be customized to execute desired functions. Like their RF counterparts, nano-optical antennas may be seen as impedance matching devices between free space radiation and the radiation/photon source. In receiving mode the antenna is capable to confine free space radiation to a sub wavelength region in the locality of the structure. With the control of emission rates and directions of quantum emitters like individual molecules or quantum dots at the nano scale enabling well-organized coupling to more conventional optical technologies could have technological applications in building single photon detectors on the nano-scale. This is especially interesting for the development of the sources required in quantum cryptography. Being the trendiest option in terrestrial TV and radio broadcasting systems, almost every rooftop featured one or more of these devices. As optical counterpart of microwave antennas, plasmonic nanoantennas are essential nano scale devices for converting propagating optical radiation into confined/enhanced electromagnetic fields. Presently, nano antennas, with a typical size of 200-500 nm, have initiate their applications in bio-sensing, bio-imaging, energy harvesting, and disease cure and prevention. With the device feature size of next generation IC goes down to 22 nm or smaller, and biological/chemical sensing reaches the Gene's level, the sizes of the corresponding nano antennas have to be scaled down to sub-100nm level.

Operational implementations of nano-optical antennas have only in recent times been demonstrated in emission mode. Antenna directionality was adequately proven in these works by far-field spectroscopic imaging of the shared space. In our work we consider experimentally the properties of nano- optical antennas in reception mode with a near-field microscope. This allows us to represent direct conclusions about the correct antenna mode of operation, which may otherwise only be inferred from simulations mimicking experimental results.

The Figure 1 show representative results from measurements with our cross-polarization Apertureless Scanning Near-field Optical Microscope (ASNOM).

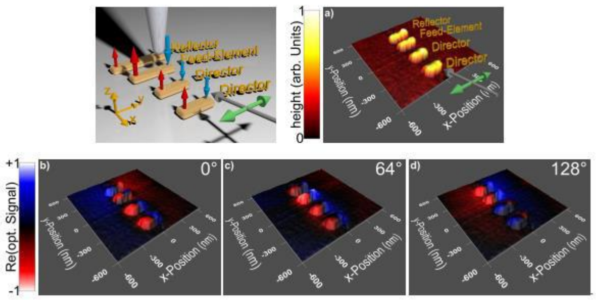

FIGURE 1: Apertureless Scanning Near-field Optical Microscope (ASNOM).

With the ASNOM being able to determine both amplitude and phase, we can recreate the field evolution of the time-harmonic reception processes. The real part of the E-fields measured above the antenna at diverse snapshots in time. The electric field strength at the particular incident of time is color coded as surface on top of the 3D topography. The fields at the occurrence of time that we denominate with the phase of 0° where the two directors light up. The two directors illustrate one positive and one negative field lobe with a field node in between them. The feed element shows a reasonably weak field amplitude, representing that the fields are close to the point in time where the signal of the field amplitude flips. Fascinatingly, the reflector shows a dipole pointing in the opposite direction with respect to the directors. The situation 64 phase degrees soon in time. All antenna elements show the same color design, representing that the dipole moments cover the same orientation. The feed element is at its best field strength, brighter than all the other elements at any time. Finally, shows the E-fields a different 64° later where the reflector reaches its maximum.

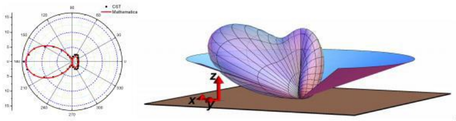

FIGURE 2:CONE SHAPED PART OF THE RADIATION PATTERN

The field strength of the feed element is previously on the way out and the dipole moments of the upstream two-faced directors have already flipped a typical directivity plot. Our oblique incident lighting scheme gives us access to a cone-shaped part of the radiation pattern with an aperture angle of approximately 140° as indicated on the right. The conical cut through the emission pattern shown on the left reveals a strong directionality. When we extract the reception characteristic for lighting under varying angles, taking the behind substrate into account, we observe excellent qualitative agreement. In summary, we have experimentally observed the complete function of nano-optical Yagi-Uda antennas in the near field. Such structures show well-built directionality in receiving mode. In the phase channel of our near-field images we examine the capacitive coupling of the director elements and the inductive coupling of the reflector element. Ahead forward lighting of the antenna, the constructive interference of scattered light by these elements leads to a strong field improvement at the position of the feed element. The understanding of amplitude and phase dynamics of the Yagi-Uda nano antenna elements is equivalent to their RF counterpart. This suggests that adjustment of existing RF antenna theories should make it feasible to transfer most of the RF engineering design rules also to nano-antennas. One feasible solution to defeat this propagation loss problem is during signal enhancement that explores hybrid plasmonic effect: plasmon polarization (SPP) coupled with localized surface plasmon (LSPR). In this dissertation, we designed a novel bottomless sub wavelength nano-antenna structure which can successfully couple the SPP

2. METALLIC NANO-ANTENNAS

A. *Plasmonic Dipole UWB Nano-antennas*

Dual-Vivaldi nano-antenna arrays were intended, fabricated, and optically characterized. The antenna arrays were characterized by measuring the scattered light at infrared and visible spectral ranges. A new technique for antenna and load impedance measurements using scattering data has been developed.The radiation efficiency and the spectral response of the antennas were initiate to be in good agreement through geometric simulations. The results presented here demonstrate the particularly wideband nature of the Dual-Vivaldi nano-antennas and the strong impact of load at the antenna terminals on its scattering response. These properties, as well as their several degrees of freedom for design, deliver the Dual-Vivaldi nano-antennas excellent candidates for optical sensing applications and energy harvesting. Various applications of nano-antennas will be discussed.

B. *Plasmonic Dimer Nano-Antenna*

We report on the fabrication and dark-field spectroscopy characterization of Au dimer nanoantennas located on top of SiO_2 nanopillars. The reported process enables the fabrication of nanopillar dimers with gaps behind to 15 nm and heights up to 1 µm. A clear hope of the plasmonic resonance situation on the dimer gap is observed for smaller pillar heights, viewing the high uniformity and reproducibility of the process. It is shown how mounting the height of nanopillars extensively affects the recorded flexible scattering spectra from Au nanoantennas.

The outcome are compared to finite-difference time-domain (FDTD) and finite-element method (FEM) simulations. Additionally, measured spectra are accompanied by dark-field microscopy images of the dimers, viewing the well-defined modify in color. Placing nanoantennas on nanopillars with a height analogous to the in-plane dimer magnitude results in an enhancement of the scattering reaction, which can be implicit through concentrated interface of the near-fields with the substrate. When increasing the pillar height more, scattering by the pillars themselves manifests itself as a well-built tail at lower wavelengths.

Additionally, well-built directional scattering is expected as a effect of the interface between the nanoantennas and nanopillars, which is in use into account in simulations. For pillars of height secure to the plasmonic resonance wavelength, the scattering spectra become new complex due to additional scattering peaks as a consequence of larger geometrical nonuniformities.

C. *Plasmonic Characterization Of Integrated Circuit With High Efficiency Nano-antennas*

Four types of nanoantennas have been intended and characterized at 1.55 µm wavelength: Dipole antenna, Yagi-Uda antenna, dipole antenna array and bowtie antenna. The spectrum, coupling efficiency, and far field radiation patterns are also investigated. We also quantitatively characterized the correlation between the couple-in efficiency and the spot size of the incident light. For the three dipole-type antennas, the couple-in and couple-out efficiencies have been precise experimentally. A plasmonic integrated circuit has also been designed and fabricated with these four types of nanoantennas.

D. *Plasmonic Bowtie Nano-antennas*

Bowtie nanoantennas characterize the extension of dimer nanoantenna model. We report on a temperature-reactive tunable plasmonic device that incorporates together bowtie nanoantenna arrays (BNAs) with a submicron-thick, thermosensitive hydrogel coating. The coupled plasmonic nanoparticles present an intrinsically higher field enhancement than conventional individual nanoparticles. The favorable scaling of plasmonic dimers at the nanometer scale and ionic distribution at the submicron scale is leveraged to attain strong optical resonance and rapid hydrogel response, respectively. We exhibit that the hydrogel-coated BNAs are able to sense environmental temperature variations. The phase transition of hydrogen leads to 16.2 nm of significant wavelength shift for the hydrogel-coated BNAs, whereas only 3 nm for the uncoated counterpart. The response time of the device to temperature variations is only 250 ms, due to the small hydrogen depth at the submicron scale.

The demonstration of the capacity of the device to tune its optical resonance in answer to an environmental stimulus suggests a possibility of making many other tunable plasmonic devices throughout the incorporation of attached plasmonic nanostructures and various environmental-responsive hydrogens.

3.DIELECTRIC NANO-ANTENNAS

An optically resonant dielectric nanostructure is a new path in nanophotonic research which gives a strong promise to tribute or alternate plasmonics in many possible application areas. The main advantages of significant dielectric nanostructures over conventional plasmonics are low victims, wide variety of applicable dielectric materials and strong magnetic resonant answer. So far most of explore in this field has been conducted with silicon as a material for nanostructures due to its one of the highest rate of refractive index at optical frequencies and CMOS compatibility. For these reasons in recent studies examine focus starts shifting towards other fitting materials such as III-V semiconductors, e.g. GaAs or GaP, and wide-bandgap semiconductors such as TiO2.

4.SYSTEM SPECIFICATION

E. ***HFSS***

Antennas are almost everywhere from commercial application such as smart phones, RFID tags ,and wireless printers, to security application such as phased array antennas for aircraft radar systems or satellite based , to provide incorporated ground based communication systems. Electromagnetic simulation is a precious tool in antenna design and platform combination providing the trendy, the ability to virtually design and estimate what if scenarios as well as verify the final artificial design.

F. ***Antenna simulation technologies in HFSS***

HFSS offers the subsequent simulation methods and tools depending upon the kind of troubles you want to solve :

1. Finite element method (Enabled with HFSS)

2. Integral equations (Enabled with HFSS-IE)

3. Physical optics (Enabled with HFSS-IE)

4. FEM Transient (Enabled with HFSS-TR)

5. Antenna design toolkit provided with HFSS including over 50 standard antenna designs.

G. ***Dielectric Yagi-uda Nano-antennas***

Conventional antennas, which are widely engaged to transmit radio and TV signals, can be used at optical frequencies as long as they are shrink to nanometer-size dimensions. Optical nanoantennas made of metallic or high-permittivity dielectric nanoparticles permit for attractive and manipulating light on the scale much slighter than wavelength of light. Based on this facility, optical nanoantennas tender unique opportunities regarding key applications such as optical communications, photovoltaics, non-classical light emission, and sensing. From a large number of suggested nanoantenna concepts the Yagi-Uda nanoantenna, an optical analogue of the deep-rooted radio-frequency Yagi-Uda antenna, stands out by its competent unidirectional light emission and development.

Following a brief introduction to the emerging field of optical nanoantennas, here we analysis recent theoretical and tentative activities on optical Yagi-Uda nanoantennas, including their intend, fabrication, and applications. We also discuss numerous extensions of the conventional Yagi-Uda antenna design for broadband and tunable action, for applications in nanophotonic circuits and photovoltaic devices.

H. ***Nano-anntennas***

The Yagi-uda nano antennas also have the prospective to act as cooling devices that illustrate waste heat from buildings or electronics without using electricity. The nano antennas intention mid-infrared rays, which the Earth constantly radiates as heat after fascinating energy from the sun during the day. In contrast, traditional solar cells can only unvisible lightinterpretation them idle after dark. Infrared radiation is an mainly rich energy source because it also is generated by industrial processes such as coal-fired plants. The nano antennas are little gold squares or spirals set in a particularly treated form of polyethylene, a material used in plastic bags. While others have successfully invented antennas that accumulate energy from lower-frequency regions of the electromagnetic spectrum, such as microwaves, infrared rays have verified more indefinable.

I. ***Dielectric Optical Nano-antennas***

Infrared near-field microscopy can be used to examine the local field of photonic structures. Near-field images of a resonant infrared antenna demonstrate the clear signature of a dipolar oscillation mode on the Au rod. The amplitude image exhibits a high signal at the rod ends which are 180° out of phase. If the antenna structure is adapted by a cut at the centre of the Au rod, the near-field images reveal two dipolar oscillation modes on the segments. Systematic studies allow to examine the coupling between the segments and to illustrate the optical properties of the antenna structures. Polarized measurements allow to filter out specific components of the optical field related to photonic structures or devices and to examine the field in the antenna gap.

5.CONCLUSION

Optical antennas are the existing tool for the manipulation of light on a nanometer scale and they are also competent of delivering optimum control over transduction in the far-field region. Present optical antenna investigate is being aggravated in particular by developments in nanofabrication technology and RF antenna analogies. Optical antennas come together the quantum methods and photon sources by including fascinating new physics, for occasion the violation of selection procedures and unconventional ways for robust pairing. The ideas of focused radiation and focused reception can be sensible to the photon emitters. Once the techniques of nanofabrication have been happen to mastered, a variety of applications will emerge, including controlled single-photon sources for quantum information, light harvesting, energy conversion, efficient biosensors, data storage, nanoscale optical circuitry and optical imaging beyond 10 nm resolution. This review has emphasized the attitude and applications of optical biosensors. An approval of optical antenna basics offers probability of tuning and controlling the optical performance. Optical antennas have a strong confidence on the shape, size and composition of the nanoparticles which transport an enhancement of biosensors' sensitivity. A wide range of investigations on optical antenna are now devoted to making substrates, which give solid improvements of the EM field and send information about attaining control of optical properties by calculating the physical factors of nanoparticles.

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