Plasmonics Topical Conference

Room: 619 - Session PL-MoA

Plasmon Dynamics and Magnetoplasmonics

Moderator: J.P. Long, Naval Research Laboratory

2:00pm **PL-MoA1 Nanoplasmonics under Coherent Control**, ***M.I. Stockman***, Georgia State University **INVITED**

Surface plasmon (SP) modes of metal nanostructures can and do localize at the nanoscale in the regions much smaller than the excitation radiation wavelength. Their minimum localization size is limited by the smallest features of the nanostructures and limits of the macroscopic electrodynamics. In practical terms, SPs can localize within just a few nanometers. Local optical fields in a plasmonic nanostructure form nano-sized hot spots where the SPs are localized. In many cases, such a hot spot is a superposition of several or many SP modes. Exciting such a nanoplasmonic system with an optical field that is a coherent superposition of different frequencies, one can impart different phases on the excited SP modes. Due to the interference of these SPs, the intensity of the corresponding hot spot can be changed: the constructive interference leads to the enhanced local fields, and the destructive one to their suppression at any given hot spot. This is a principle of the coherent control of nanoplasmonic energy concentration at the nanoscale proposed theoretically in our paper.[1] The coherent control can be implemented by both continuous-wave excitation and ultrashort pulses that can be considered as a coherent superposition of wide band of harmonics. Since this publication, this coherent control at the nanoscale has been both significantly developed theoretically.[2] and observed experimentally.[3] In this talk, we review the existing knowledge on the ultrafast coherent control of nanoscale optical energy localization in surface plasmonics. We also discuss the latest theoretical ideas including the time-reversal coherent control,[4] carrier-envelope phase effect,[5] and the spatio-temporal coherent control.[6]

[1]M. I. Stockman, S. V. Faleev, and D. J. Bergman, Coherent Control of Femtosecond Energy Localization in Nanosystems, Phys. Rev. Lett. 88, 67402 (2002)

[2]See, e.g., M. I. Stockman, D. J. Bergman, and T. Kobayashi, Coherent Control of Nanoscale Localization of Ultrafast Optical Excitation in Nanosystems, Phys. Rev. B 69, 054202-10 (2004); T. Brixner, F. J. G. d. Abajo, J. Schneider, and W. Pfeiffer, Nanoscopic Ultrafast Space-Time-Resolved Spectroscopy, Phys. Rev. Lett. 95, 093901-1-4 (2005); M. Sukharev and T. Seideman, Phase and Polarization Control as a Route to Plasmonic Nanodevices, Nano Lett. 6, 715-719 (2006)

[3]A. Kubo, K. Onda, H. Petek, Z. Sun, Y. S. Jung, and H. K. Kim, Femtosecond Imaging of Surface Plasmon Dynamics in a Nanostructured Silver Film, Nano Lett. 5, 1123-1127 (2005); M. Aeschlimann, M. Bauer, D. Bayer, T. Brixner, F. J. G. d. Abajo, W. Pfeiffer, M. Rohmer, C. Spindler, and F. Steeb, Adaptive Subwavelength Control of Nano-Optical Fields, Nature 446, 301-304 (2007)

[4]X. Li and M. I. Stockman, Time-Reversal Coherent Control in Nanoplasmonics, arXiv:0705.0553 (2007); Phys. Rev. Lett. (Submitted)

[5]M. I. Stockman and P. Hewageegana, Absolute Phase Effect in Ultrafast Optical Responses of Metal Nanostructures, Appl. Phys. A (2007) (In Print)

[6]M. Durach, A. Rusina, K. Nelson, and M. I. Stockman, Toward Full Spatio-Temporal Control on the Nanoscale, arXiv:0705.0725 (2007)

2:40pm **PL-MoA3 Metal Colloids Nano-Antenna for Local Linear and Nonlinear Optical Response**, ***P. Guyot-Sionnest***, *M. Liu*, University of Chicago **INVITED**

The optical absorption and scattering of metal colloids is strongly shape dependent due to collective Plasmon resonances. Such particles are attractive for future optical integration. In particular, very large local electric field can also be achieved, both inside and outside the metal particles, providing means to locally enhance the linear and nonlinear optical response of the colloids and their environment. Of primary interest are structures in which one plasmon mode dominates the spectral response. These are typically elongated structures which exhibit the narrowest spectral response and large field enhancements. An example of such structure is an elongated bipyramid shape recently synthesized for Au colloids. For small particles in the dipole limit, the limiting linewidth of a Plasmon is due to dissipation inherent to the metal and to additional effects of the surface. In this context I will describe Au/Ag core/shell systems. Finally, achieving large nonlinear optical response, so that fast optical switching can be made at the single particle level is an ongoing challenge and initial results on Au nanorods will be presented.

3:40pm **PL-MoA6 Ultrafast Microscopy of Surface Plasmon Dynamics in Silver Films**, ***H. Petek***, University of Pittsburgh **INVITED**

We study the dynamics of localized surface plasmons and propagating surface plasmon polaritons in nanostructured Ag films on femtosecond temporal and nanometer spatial scale by means of interferometric time-resolved two-photon photoelectron emission microscopy (ITR-PEEM). Identical, phase correlated pump-probe pulses excite two-photon photoemission mediated by surface plasmon excitation in silver films; the resulting electron emission is imaged with electron optics. The combination of laser excitation an electron imaging provides <10 fs temporal and 50 nm spatial resolution. We record movies of surface plasmon propagation, dispersion, dephasing, interference and focusing in nanolithographically patterned metal films. The ITR-PEEM method provides a revolutionary advance in ultrafast electron microscopy for visualizing and controlling electromagnetic fields and ultrafast processes on the nano-femto scale.[1,2].

[1]A. Kubo, K. Onda, H. Petek, Z. Sun, Y.-S. Jung, and H.-K. Kim, Nano Letters 5, 1123 (2005).
[2]A. Kubo, N. Pontius, and H. Petek, Nano Lett. 7, 470 (2007).

4:20pm **PL-MoA8 Ultrafast Studies of Gold, Nickel, and Palladium Nanorods**, ***J.C. Owrutsky***, *A.D. Berry*, Naval Research Laboratory, *G.M. Sando*, Malvern Instruments

Steady state and ultrafast transient absorption studies have been carried out for gold, nickel, and palladium high-aspect ratio nanorods. For each metal, nanorods were fabricated by electrochemical deposition into ~6 μm thick polycarbonate templates using two nominal pore diameters (10 nm and 30 nm, resulting in nanorod diameters of about 40 and 60 nm, respectively). Static spectra of the nanorods for each metal reveal a mid infrared longitudinal surface plasmon resonance (SPR) band as well as a transverse SPR band in the visible for the gold and larger diameter nickel and palladium nanorods. This demonstrates that high aspect ratio nanorods of transition metals have mid infrared SPR bands. Time resolved studies were performed on the gold and nickel nanorods with subpicosecond resolution, 400 nm excitation, and a wide range of probe wavelengths from the visible to the mid-IR as well as using infrared excitation (near 2000 cm^{-1}) and probing at 800 nm. The dynamics observed for both diameters of gold and nickel nanorods include transients due to electron - phonon coupling and impulsively excited coherent acoustic breathing mode oscillations, which are similar to those previously reported for spherical and smaller rod-shaped gold nanoparticles. The results demonstrate that the dynamics of high aspect ratio metal nanorods resemble those for smaller nanoparticles.

4:40pm **PL-MoA9 Magnetoplasmonic Effects in Au/Co/Au Nanodisks**, ***G. Armelles***, Instituto de Microelectrónica de Madrid (IMM-CNM-CSIC), Spain, *J.B. González-Diaz, A. Garcia-Martin, R. Asenjo, J.M. Garcia-Martin, A. Cebollada*, IMM-CNM-CSIC, Spain, *B. Sepulveda, Y. Alaverdyan, M. Käll*, Chalmers University of Technology, Sweden, *L.l. Balcells*, ICMAB-CSIC, Spain

Noble metal-Ferromagnetic metal nanodisks exhibiting simultaneously localized surface plasmon resonances and magneto-optical (MO) activity were prepared from continuous Au/Co/Au films by colloidal lithography. Up to now, such phenomena have been only observed in continuous films made of Au/Co/Au trilayers. This system exhibits simultaneously well defined propagating surface plasmon resonaces and MO activity,[1] and have been the basis to develop new high sensitive biosensors.[2] However, a nanostructured system exhibiting localized surface plasmon resonances (LSPR) has two main advantages: i) the strong localization of the electromagnetic field around the nanostructures suggests a noticeable enhancement in the MO properties; ii) the spatial localization of electromagnetic fields associated with these resonances would make such a system a promising candidate for the development of high spatial specificity magneto-plasmonic sensing devices. Even though complex onion-like nanoparticles made of noble metals and ferromagnets that exhibit LSPR have been obtained using different chemical methods,[3] no MO activity has been reported in any of them. In this work we show for the first time that such active nanostructures exhibiting optical and MO properties can actually be obtained. The nanodisks (60-110nm diameter) were prepared by colloidal lithography from Au/Co/Au films grown onto glass by sputtering. The absorption spectra of the samples exhibit a peak around 2 eV that can be associated to the LSPR of the nanodisks. As we increase the disk diameter the energy position of the peak shifts towards lower energies. The MO activity was determined measuring the Polar Kerr rotation and ellipticity spectra. These spectra present a well defined structure in the same energy region than that of the absorption peak. Moreover, an enhancement of the MO activity is also observed. The results will be explained with the help of theoretical simulations made with a scattering matrix formalism that takes into account the MO activity.

[1] C.Herman et al. Phyts. Rev. Lett 73,3584(1994)
[2] B. Sepúlveda et al. Oppt Lett.31,1085 (2006)
[3] Z.Ban et al J. Mater. Chem 15, 4660 (2005); J. Zhang et al. J. Phys. Chem B 110, 7122 (2006); S. Mandal et al J. Mater. Chem 17 , 372 (2007); N. S. Sobal et al. Nano Letters 2, 621 (2002).

5:00pm **PL-MoA10 Magnetoplasmonic Activity in Systems with Interacting Localized and Extended Surface Plasmon Modes**, *A. Garcia-Martin, J.B. Gonzalez-Diaz,* ***A. Cebollada****, J.M. García-Martin, G. Armelles,* IMM-CNM-CSIC, Spain, *M.U. González, G. Badenes, R. Quidant,* ICFO, Spain

In the last years, plasmonics has consolidated as a powerful approach to obtain photonic devices with novel capabilities. To get this progress forward, important efforts are dedicated to developing active and/or externally controlled systems. Magnetic fields can influence the propagation of surface plasmon polaritons (SPP),[1] so the mixing of magnetic and plasmonic materials seems a promising approach for obtaining these externally controlled systems. Up to now, multilayers of noble and magnetic metals have been analyzed and they have shown to present both plasmonic and magneto-optic (MO) effects. Moreover, the MO effect is enhanced in the presence of an excited plasmon in the system.[2] In this work, we present the study of the MO and plasmonic activity in structures exhibiting both SPP and localized surface plasmons (LSP). The samples consist on a continuous Au/Co/Au trilayer deposited on glass by sputtering, covered with a dielectric spacer of SiO2 on top of which an array of Au nanodiscs (100 nm in diameter) have been fabricated by electron beam lithography. This system presents two kinds of surface plasmon resonances: The Au nanoparticles sustain LSP, and the trilayer/silica interface SPP, which can be excited by means of the Au nanoparticles grating. By controlling the parameters of the nanoparticles array, the relative positions of the two plasmon resonances of the system can be engineered.[3] The trilayer also presents MO properties due to the presence of the Co layer. The MO properties of the system have been analyzed measuring the polar Kerr rotation and ellipticity spectra. The trilayer/nanoparticles system shows a different spectrum from that of the trilayer alone. In particular, an increase of the MO signal in the trilayer/nanoparticle spectra appears at the spectral position of the LSP. This increase depends on the coupling strength between the LSP and the SPP, which can be controlled by the periodicity of the array and the thickness of the dielectric spacer. These results open the door to the design of active magnetoplasmonic devices based on interacting localized and propagative surface plasmon modes.

[1] B. Sepúlveda, L. M. Lechuga and G. Armelles, J. Lightwave Technol. 24, 945-955 (2006).
[2] C. Hermann et al., Phys. Rev. B 64, 235422 (2001).
[3] J. Cesario, R. Quidant, G. Badenes and S. Enoch, Opt. Lett. 30, 3404 (2005).

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