The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

Winter College on Optics:

Advances in Nano-Optics and Plasmonics

(6-17 February 2012 - SMR2328)

LAMP Seminars
session I

ABSTRACTS

(Wednesday, 8 February 2012)

Surface plasmon propagation in metal nanostrip waveguide structures with anisotropic substrates

Anju Babu[1] and Vincent Mathew[2]
[1]Postgraduate and Research Department of Physics,
St. Thomas College, Palai, Kerala - 686574, India
[2] Department of Physics, Central University of Kerala,
Kasaragode, Kerala - 671328, India.
Email: anjubabu05@gmail.com, Ph. 09995710478

Plasmonics have gained significant attention for its ability to manipulate the flow of light down to subwavelength scale, using nanoscale metallic structures [1]. Surface plasmon polaritons, or the propagating modes of the electron plasma oscillations at the surface of a metal coupled with an electromagnetic wave, has been realized in various geometries [2] ranging from simple metal-insulator interface to complex structures consisting of metal stripes surrounded by dielectric materials [3]. Plasmonic devices enable an improved synergy between the electronic and photonic devices as it naturally interfaces with the size of electronic components and operating speed of photonic network [4, 5]. The practical use of SPP waveguides is often limited due to the losses occurring in the metal film which leads to low propagation range. Manipulations with the waveguide geometries and surrounding structures have led to significant progress in fabrication of effective plasmonic waveguides.

We analyze plasmon wave propagation through certain waveguide structures and study the guiding properties of these plasmonic waveguides, with a nanoscaled metal film having a frequency dependent dielectric function, embedded in a dielectric environment. The various structures that are considered are: (1) Layered structures with metal (semi-infinitely wide) film having homogeneous interfaces [6], and (2) Layered structures with metal film of finite width (metal strip) having inhomogeneous interface [7]. The dispersion relation for the SPP modes supported by infinitely wide waveguide structures is analytically derived by defining and solving a boundary value problem based on Maxwell's equations [6]. The matching of tangential field components at the interface between each layer leads to the dispersion relation. The analytical derivation of dispersion relation for the finite width metal film waveguide is practically difficult due to the inhomogeneous nature of the waveguide structure at the metal/dielectric interfaces. We employ the method of lines (MoL), a finite difference based semi-analytical scheme for constructing dispersion relation numerically. Application of boundary matching conditions at layer interfaces leads to a homogeneous matrix equation and non-trivial solution of which gives the propagation constant [8]. Numerical root search in complex domain is carried out using both the Nelder-Mead minimization approach [9] and the direct root search based on Muller's method [10].

Metal nano-strip is an important waveguiding geometry as it offers two dimensional confinement of plasmon wave and is useful for designing various components in integrated plasmon optics. We have analyzed the properties of the fundamental modes propagating in a metal strip waveguide surrounded by dissimilar dielectric materials (asymmetric structure) [11]. Owing to the versatile effects of anisotropy in mode propagation and control, we have considered an asymmetric strip waveguide with an anisotropic (uniaxial and biaxial material) substrate and an isotropic cladding [12]. The propagation properties of the four fundamental modes (ss_b, as_b, sa_b and aa_b) in the asymmetric waveguide structure are studied as function of the metal thickness [7]. Figure 1 and Figure 2 shows the dispersion curves of an asymmetric strip waveguide structure, with a uniaxial and a biaxial anisotropic substrate, respectively. As a limiting case, modes guided through an asymmetric slab (infinitely wide metal film) waveguide are also analyzed for both the cases. The non-degenerate nature of the modes in the anisotropic material based strip waveguide facilitates the possibility of single mode excitation in integrated optical circuits. Thus it is observed that by properly choosing the substrate material we can modify the propagation characteristics of the modes supported by the waveguide structure.

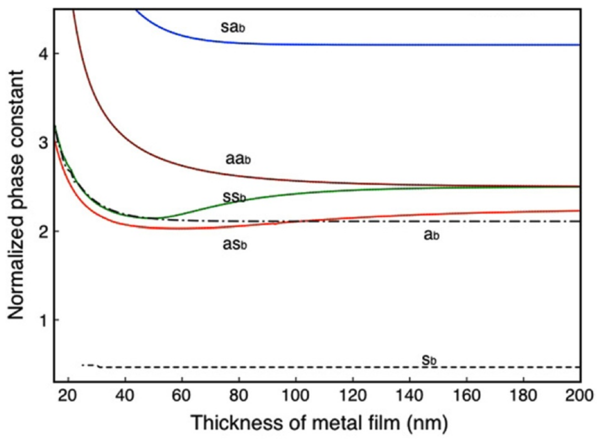

Figure.1 Variation of normalized phase constant with thickness of metal film of width w=1 μm of the four fundamental modes for an asymmetric waveguide with a uniaxial anisotropic substrate. The a_b and s_b modes in a corresponding slab waveguide ($w = \infty$) are also shown.

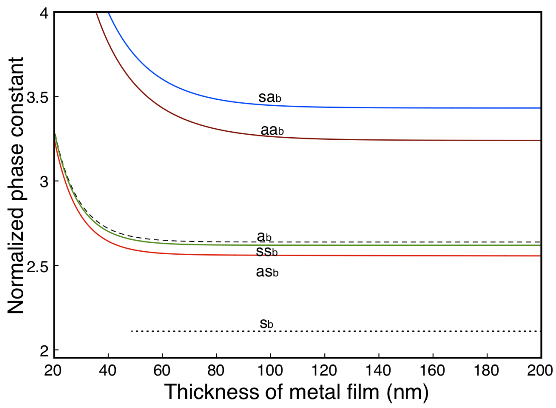

Figure.2 Variation of normalized phase constant with thickness of metal film of width w=1 μm of the four fundamental modes for an asymmetric waveguide with a biaxial anisotropic substrate. The a_b and s_b modes in a corresponding slab waveguide ($w = \infty$) are also shown.

Acknowledgement

The authors thank the Department of Science and Technology, Government of India for the financial support through a research grant (No. SR/S2/CMP-0012/2009).

References

[1] R. Zia, M. D. Selker, P. B. Catrysse, and M. L. Brongersma, "Geometries and materials for subwavelength surface plasmon modes", Journal of Optical Society of America, 21, 12, (2004).

[2] S. A. Maier and H. A. Atwater, "Plasmonics: Localization and guiding of electromagnetic energy in metal/dielectric structures", Journal of Applied Physics, 98, 011101, (2005).

[3] P. Berini, "Plasmon polariton waves guided by thin lossy metal films of finite width: Bound modes of symmetric structures", Phy. Rev. B., 61, 10484, (2000).

[4] A. Derigon and D. R. Smith, "Numerical simulation of long range plasmon", Opt.Express, 14, 1611, (2006).

[5] W. Cai, W. Shin, S. Fan and M. L. Brongersma, “Elements for plasmonic nanocircuits with three dimensional slot wavegiudes”, Adv Mater., 22, 5120, (2010).

[6] J. A. Dionne, L. A. Sweatlock, H. A. Atwater and A. Polman, ”Plasmon slot waveguides: Towards chip-scale propagation with subwavelength-scale localization”, Physical Review B, Vol. 73, No. 035407, (2006).

[7] P. Berini, “Plasmon polariton modes guided by a metal film of finite width”, Opt. Lett., 24, 1011, (1999)

[8] P. Berini and K. Wu, “Modelling Lossy Anisotropic Dielectric waveguides with the Method of Lines”, IEEE Trans. Microwave Theory Tech., 44, 749, 1996.

[9] W. H. Press, S. A. Teukolsky, W. T. Vellerling and B. P. Flannery, “Numerical recipes in Fortran”, Cambridge: Cambridge University Press, (1996).

[10] J. H. Mathews and K. D. Fink, “Numerical Methods using MATLAB”, Prentice-Hall, (2004).

[11] P. Berini, “Plasmon polariton waves guided by thin lossy metal films of finite width: Bound modes of asymmetric structures”, Phy. Rev. B, 63, 125417, (2001).

[12] A. Babu, C Bhagyaraj, G. Mathew and V. Mathew, “Dispersion of plasmon polaritons guided by a metal film of finite width deposited on a uniaxial substrate”, J. Phys. D: Appl. Phys., 44, 335301, (2011).

Preference: oral

Biofunctionalization of plasmonic nanostructured surfaces for detection devices

Maria Antonieta Daza Millone

Centro Atomico Bariloche, CAB
Laboratorio de Fotonica y Optoelectronica
San Carlos De Bariloche
Río Negro
Argentina

Abstract

Surface Plasmon Resonance (SPR) biosensors are widely used to detect low concentration of any kind of molecules without label requirements. The detection principle is based in specific interactions between a biorecognition agent (antibodies, nucleic acids, enzymes, etc) and the analyte. From the applied point of view, a great effort is necessary to achieve the optimization of the process of modification and biofunctionalization of the transducers (gold surface in the device) in order to obtain bioactive stable and reproducible layers which are able to minimize the unspecific adsorption effects. For small molecules (MW < 1kDa) competitive indirect assays are necessary in order to improve the detection.

Preference: oral

Quantum correlations of radiation emitted by a quantum well in a microcavity

Hichem Eleuch

Institut National des Sciences Appliquees de Technologie (INSAT)
Tunis, Tunisia

Abstract

We consider a semiconductor quantum well in a microcavity driven by coherent light. We explore the dynamics of the entanglement. We show the presence of sudden birth and sudden death for some particular sets of the system parameters.
Furthermore we study the effect of exciton-photon detuning, external coherent light, and the squeezed vacuum. reservoir on vacuum Rabi splitting and on quantum statistical properties of the light emitted by the quantum well. We show that the exciton-photon detuning leads to a shift in polariton resonance frequencies and a decrease in fluorescence intensity. We also show that the fluorescent light exhibits quadrature squeezing, which predominately depends on the exciton-photon detuning and the degree of the squeezing of the input field.

Preference: oral

Design And Evaluation Of Millimeter-Wave Photonic Transmitter Modules For Radio-over-Fiber Applications

Ivan Flammia

Center of Semiconductor
Technology and Optoelectronics -
University of Duisburg-Essen
Germany

Abstract

Radio-over-Fiber (RoF) technology is potentially able to provide multi-gigabit data rates, allowing **"fiber-like" wireless connectivity** for the expansion of existing mobile networks (backhauling and last-mile coverage) as well as for indoor applications. The recently world-wide allocated bands (**71-76 GHz** and **81-86 GHz**) offer unequaled spectrum bandwidth for wireless communication but require the development of new devices, specifically designed for analog applications. In particular, a **photonic transmitter** converts the optical signal delivered by an optical fiber into en electrical signal by means of a photodiode and transmits the RF power through an opportune antenna. Key requirements are an optimum adapted bandwidth (reduced noise) and a rectangular waveguide (WR) output. Thanks to their low loss and high power handling capability, WRs are widely used as antenna feed; at higher frequencies their dimensions shrink significantly, making WRs light and flexible, thus even more desirable for analog applications.
This presentation will describe a novel concept for a 71-76 GHz photonic transmitter, allowing a **quasi-hermetic packaging** of optical and electronic components. **Simulation results** as well as **experimental validation** will be presented.

Preference: oral

Optical biosensors for detection of the bacteria existing at the aquatic environment

P. Gluchowski [1], K. Halubek - Gluchowska[1,2], J. Rybka [2], W. Strek[1], D. Hreniak [1]

[1] Institute of Low Temperature and Structure Research, Polish Academy of Sciences, Wroclaw [2] Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, Wroclaw

Abstract

Silicate thin films covalently bound with selected biological molecules labeled with luminophores were prepared. The optical properties of the system were measured. The influence of LPS (lipopolysaccharide isolated from Hafnia alvei PCM 1186 bacteria) on the spectroscopic properties of the dye – protein conjugates were shown. The system based on the silicate thin films covered by conjugates has been proposed as a optical biosensor for the bacteria detection.

Preference: oral

Plasmonic nanostructuring by Ion beams

Manish Kumar

Inter University Accelerator Centre, India

Abstract

Energetic ions, depending on their mass and energy, have different roles in materials science. Experiments in this field has opened the possible nanostruring of materials for plasmonic applications. In this talk, experimental results on the ion induced synthesis of plasmonic nanocomposites and modification of size and shape of nanostructures in plasmonic nanocomposites are presented. Some results on engineering of optical properties by ion beam induced surface engineering are also presented.