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Abstracts - Symposium K: Materials for High-Performance Photonics

- **2011 MRS Fall Meeting & Exhibit**
- **November 28 - December 2, 2011**
- **Hynes Convention Center, Boston, MA**
- **Meeting Chairs:** Cammy R. Abernathy, Paul V. Braun, Masashi Kawasaki, Kathryn J. Wahl

SYMPOSIUM K

Materials for High-Performance Photonics

November 28 - 30, 2011

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* Invited paper

SESSION K1: Photonics I
Chair: Thomas Cooper
Monday Morning, November 28, 2011
Independence E (Sheraton)

8:00 AM *K1.1

Degenerate and Nondegenerate Nonlinear Spectroscopy. Eric Van Stryland, David Hagan, Scott Webster, Dmitry Fishman, Honghua Hu, Trenton Ensley and Markus Seidel; CREOL, University of Central Florida, Orlando, Florida.

We will describe methods for rapidly characterizing the spectrum of nonlinear optical absorption as well as the dispersion of the nonlinear refraction in materials including semiconductors and organic dyes. A weak White-Light Continuum (WLC) can be used as the probe in pump-probe experiments and thus yield the spectrum of the nondegenerate nonlinear absorption. Kramers-Kronig integrals can then be used on the nondegenerate spectra to calculate the dispersion of the nonlinear refraction. Temporally delaying the probe gives information on the temporal dynamics of the nonlinear material. Alternatively, the WLC Z-scan relies on a spectrally intense femtosecond WLC which we have recently succeeded in making available over more than an octave bandwidth using ~150 fs pulses at 780 nm weakly focused into a ~1 m tube filled with krypton gas at ~2.5 atm. By seeding the WLC with a very weak (~0.02% of the pump beam) visible pulse we can increase the total energy in the continuum by >3x to obtain a few nJ/nm spectral energy density. Thus, WLC Z-scan experiments can simultaneously yield the nonlinear absorption spectrum and index dispersion for frequency degenerate nonlinearities. Such experiments have provided a wealth of data on the third-order nonlinear response of materials. Recently we demonstrated orders of magnitude enhancement in the two-photon absorption (2PA) coefficient of direct bandgap semiconductors when going to extremely nondegenerate photon pairs (i.e. energy ratios of ~10/1) which is in excellent agreement with a simple 2-parabolic band model. This has allowed gated detection of subgap radiation, including IR detection, using wide-gap semiconductors. Further applications, such as all-optical switching, should be possible. In addition, the inverse process of 2-photon gain should be identically enhanced, making the likelihood of a 2-photon semiconductor laser realistic. Analogous processes in organic materials are under study. Measurements of nonlinearities as a function of pulsewidth can further help determine the dynamics of the nonlinear response. Separating the bound electronic and nuclear contributions to the nonlinear refractive index, n2, is of interest to fully understand the nonlinear mechanisms in many materials but particularly for organic dyes. A detailed study of CS2 shows that measurements of n2 using pulses <50 fs are dominated by the bound-electronic response, while as the pulsewidth is increased nuclear contributions become dominant. A simple model of the kinetics shows the magnitude and temporal response of each nonlinear contribution to n2. Extending these models and measurements to organic dyes is underway.

8:30 AM *K1.2
Chromophores for Nonlinear Absorption at Telecommunications Wavelengths. Chantal Andraud, UMR CNRS-UCBL 5182, Ecole Normale Superieure de Lyon, Lyon Cedex, France.

We will present two different families of chromophores (heptamethine cyanines[1] and aza-bodipy[2]) for two-photon absorption (TPA) based optical power limiting in the IR (particularly at telecommunications wavelengths). Spectroscopic properties of molecules will be discussed in this purpose[3, 4]. Optical power limiting will be presented on the basis of TPA and excited state absorption (ESA) properties. [1] P.-A. Bouit, G. Wetzel, G. Berginc, B. Loiseaux, L. Toupet, P. Feneyrou, Y. Bretonnière, K. Kamada, O. Maury, C. Andraud Chem. Mat. 2007, 19, 5325- 5335; P.-A. Bouit, R. Westlund, P. Feneyrou, O. Maury, M. Malkoch, E.Malmström, C. Andraud New J. Chem 2009, 33, 964-968. [2] P.-A. Bouit, K. Kamada, P. Feneyrou, G. Berginc, L. Toupet, O. Maury, C.Andraud Adv. Mat. 2009, 21, 1151-1154. [3] P.-A. Bouit, C. Aronica, L. Toupet, B. Le Guennic, C. Andraud, O. Maury JACS 2010, 132, 4328-4335. [4] Q. Bellier, S. Pégaz, C. Aronica, B. Le Guennic, C. Andraud, O. Maury Org. Lett. 2011, 13, 22-25.

9:00 AM K1.3
Principles and Applications of Small Molecule Assemblies for Organic Third-Order Nonlinear Integrated Optics. Ivan Biaggio, Physics, Lehigh University, Bethlehem, Pennsylvania.

For applications in third-order nonlinear integrated optics it is necessary to develop organic materials that combine a large third-order susceptibility, a high optical quality, and the ability to integrate them with existing guided wave technology. This work will discuss how this aim was achieved by developing optimized small molecules and their corresponding dense single-component supramolecular assemblies. While larger molecules can have larger third-order polarizabilities, they are generally more difficult to handle and to assemble into a dense solid state where their nonlinearity is not diluted. Small molecules, on the other hand, can be

chromophores and the need to take electron correlation effects properly into account, a sufficiently accurate analysis of the nonlinear response of cyanines is a challenging task for modern computational chemistry. In this talk, I will discuss our recent results for several promising cyanines using a combined approach of density-functional theory and configuration interaction methods. In particular, I will discuss the influence of solvents and counterions as well as the impact of aggregation on the ground- and excited-state electronic properties of cyanine molecules.

11:30 AM K4.7

Nanoimprinted Hybrid Silica Coatings: A Versatile Tool for Light Manipulation. Alban A. Letailleur[1,2,3], Cedric Boissiere[2], Francois O. Ribot[2], Clement Sanchez[2], Jeremie Teisseire[1], Etienne Barthel[1], Elin Sondergard[1], Christophe Couteau[3], Gilles Lerondel[3] and Nicolas Chemin[4]; [1]Surface du Verre et Interfaces, Saint-Gobain Recherche, Aubervilliers Cedex, France; [2]Laboratoire de Chimie de La Matière Condensée de Paris, Collège de France - Université Pierre et Marie Curie, Paris, France; [3]ICD - Laboratoire de Nanotechnologies et d'Instrumentation Optique, Université de Technologie de Troyes, Troyes, France; [4]Composites and Coatings, Saint-Gobain Recherche, Aubervilliers, France.

In light emitting devices, a large amount of the light produced by the active layer is trapped inside the device because of internal reflection. Patterning the different interfaces induces an index gradient and light scattering and can therefore lead to an increase of the light output. Among the existing methods, Nanoimprint Lithography (NIL) emerges as a simple route for surface patterning at the sub-micrometer scale over large areas. To avoid multiple step processing and the poor stability of polymers resins, imprint of functional materials is required. Hybrid sol-gel materials form an innovative class of resists for NIL. They are based on the solution processing of organic precursors to obtain metal oxide. For instance we previously demonstrated the replication of patterns with sub-100 nm lateral size and aspect ratio greater than 1 into hybrids sol-gel silica (1). A combination of low viscosity and high reactivity enables fast and conformal imprint over several tens of cm2. (2) Furthermore, we demonstrate how the elaboration chemistry of the materials can be modified to adjust the process.(3) Due to their low dielectric constant, nanopatterned silica coatings are very suitable for direct applications in photonics, and integration in displays. Finally, tanks to the versatility of the sol-gel processing, other functionalities have been added to obtain multifunctional coatings. For instance, it was possible to graft NLO chromophores such as 2,4-dinitrophenylamine into the silica network and to successfully imprint the resulting layer. In the context of displays and lighting, we developed the introduction of colloidal quantum dots inside the patterned silica layer.(4) This last system is suitable for light conversion and extraction. As it absorbs around 400 nm and emits light in the visible range, such a layer can act as a conversion layer in LED devices. Moreover, the light output in the patterned area increased 60 % compared to the flat surfaces. References: 1) Peroz, C.; Chauveau, V.; Barthel, E.; Sondergard, E. Advanced materials 2009, 21, 555 2) Letailleur, A.; Teisseire, J.; Chemin, N.; Barthel, E.; Sondergard, E. Chem. Mater. 2010, 22, 3143 3) A. A. Letailleur, F. Ribot,, C. Boissière, C. Sanchez, J. Teisseire , E. Barthel, N. Chemin, J Am Chem Soc, submitted. 4) A. A. Letailleur, Th. Richardot, C. Boissière, C. Sanchez, C. Couteau, G. Lérondel, E. Barthel, E. Søndergård, N. Chemin, and François Ribot, Advanced materials, submitted.

11:45 AM K4.8

Hybrid Silicon Nitride and Colloidal Nanocrystal Waveguides and Microdisks: A Highly Versatile Test Bed for Visible to near-Infrared Active Integrated Photonics. Bram De Geyter[1,2,3], Katarzyna Komorowska[1,3], Zeger Hens[2,3] and Dries Van Thourhout[1,3]; [1]Photonics Research Group, INTEC, Ghent University IMEC, Gent, Belgium; [2]Physics and Chemistry of Nanostructures, Inorganic and Physical Chemistry Departement, Ghent University, Gent, Belgium; [3]Center for Nano- and Biophotonics (NB-Photonics), Ghent University, Gent, Belgium.

Recent advances in colloidal nanocrystal synthesis have extended the material's library greatly to more complex colloidal heterostructures. These new heterostructures are engineered to solve intrinsic problems of colloidal quantum materials, such as ultrafast multiexciton Auger recombination and overall material stability. These new properties, together with their ease of production and processing, and the tunability of their optical properties, make them excellent candidates to render passive integrated photonic devices on silicon-on-insulator, silica and silicon nitride, active. In this work, we present an extensive study of hybrid silicon nitride colloidal nanocrystal device integration. We report on the process optimization for fabricating hybrid

hybrid silicon nitride colloidal nanocrystal device integration. We report on the process optimization for fabricating hybrid waveguides and microdisks and prove the versatility by applying visibly-emitting 'giant' dot-in-dot CdSe/CdS/ZnS, CdSe/CdS dot-in-rod and near-infrared emitting PbSe/CdSe and PbS/CdS dot-in-dot. We report on the optical and chemical stability of these materials throughout the processing and investigate the optical performance of the hybrid waveguides and resonators.

SESSION K5: Photonics IV
Chair: Steven Flom
Tuesday Afternoon, November 29, 2011
Independence E (Sheraton)

1:30 PM K5.1

Strong Multimode Photonic Microresonator and Nanoparticle Interactions. Yasha Yi[1,2] and Patricia Pignalosa[1]; [1]NYU and CUNY, New York City, New York; [2]Massachusetts Institute of Technology, Cambridge, Massachusetts.

We have demonstrated strong multimode photonic microresonator and nanoparticle interactions by using an integrated micro disk resonator from through port of the laser coupling bus waveguide. In addition to the fundamental resonance mode, disk resonator has higher order resonance modes. The excited higher order mode has a node at the position where the electromagnetic energy of the fundamental mode is close to a maximum. Here we report that a self referencing mechanism can be achieved by simultaneous excitation of both fundamental and 2nd order micro disk optical resonance modes. Additionally, we are able to measure the area around the maximum of the fundamental resonance mode and the node of the higher order mode, which have overlaps in the disk. In this work, we used on chip disk microresonator as the example, as a variety of types of optical microresonators have been investigated; we used nanoparticle to interact with the two optical resonance modes excited by the coupling bus waveguide, where the nanoparticle can be either dielectric materials or metallic materials. The strong photonic microresonator and nanoparticle interactions has variety of applications for optical switches, waveguides and detection. The self-referencing characteristics of the two optical resonance modes have potential to achieve photonic functions independent of external perturbation, such as temperature change.

1:45 PM K5.2

Highly Efficient Double-Doped Solid-State White Light-Emitting Electrochemical Cells. Chih-Teng Liao[1], Yu-Chun Shen[1], Hsiao-Fan Chen[2], Hai-Ching Su[1] and Ken-Tsung Wong[2]; [1]Institute of Lighting and Energy Photonics, National Chiao Tung University, Tainan, Taiwan; [2]Department of Chemistry, National Taiwan University, Taipei, Taiwan.

White organic light-emitting diodes (OLEDs) based on polymers and small-molecule materials have attracted intense attention due to their potential applications in flat-panel displays and solid-state lighting. Compared with conventional white OLEDs, solid-state white light-emitting electrochemical cells (LECs) possess several promising advantages. LECs generally require only a single emissive layer, which can be easily processed from solutions, and can conveniently use air-stable electrodes. The emissive layer of LECs contains mobile ions, which can drift toward electrodes under an applied bias. The spatially separated ions induce electrochemical doping (oxidation and reduction) of the emissive materials near the electrodes, i.e. p-type doping near the anode and n-type doping near the cathode. The doped regions induce ohmic contacts with the electrodes and consequently facilitate the injection of both holes and electrons, which recombine at the junction between p- and n-type regions. As a result, a single-layered LEC device can be operated at very low voltages (close to E_g/e, where E_g is the energy gap of the emissive material and e is elementary charge) with balanced carrier injection, giving high power efficiencies. Furthermore, air-stable metals, e.g. Au and Ag, can be used since carrier injection in LECs is relatively insensitive to work functions of electrodes. In this work, we report highly efficient solid-state white LECs based on a double-doped strategy, which judiciously introduces an orange-emitting guest, $[Ir(ppy)_2(dasb)]^+(PF_6^-)$ (where ppy is 2-phenylpyridine and dasb is 4,5-diaza-9,9'-spirobifluorene) into a single-doped emissive layer comprising of an efficient blue-green emitting host, $[Ir(dfppz)_2(dtb\text{-}bpy)]^+(PF_6^-)$(where dfppz is 1-(2,4-difluorophenyl)pyrazole and dtb-bpy is [4,4'-di(tert-butyl)-2,2'-bipyridine]) and a red-emitting guest, $[Ir(ppy)_2(biq)]^+(PF_6^-)$