DOPS General Assembly 2011

Abstracts:

Ultimate light confinement with plasmonics

Sergey I. Bozhevolnyi

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Starting from the time of Archimedes death rays, people have been trying to focus light as efficiently and to as small areas as possible, having various purposes in mind: from means of destruction to renewable energy sources. In this talk, I will discuss the fundamental physical principles governing the process of radiation focusing and limitations imposed by laws of nature. I will then present the latest research results demonstrating the possibility of squeezing light into nanometer-sized volumes by using special electromagnetic waves supported by metal-dielectric interfaces [1,2], so called plasmon waves (hence plasmonics in analogy with photonics). Finally, table-top realizations of optical black holes [3] that can be thought of being ultimate light concentrators will be discussed. In particular, the recently suggested configuration [4] with gap surface plasmons propagating in space limited by spherical metal surfaces (Fig. 1) will be considered in detail.

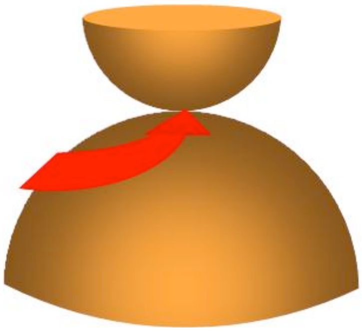

Fig. 1. Schematic representation of a plasmonic black hole [4].

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Plasmon-improved coupling of light into silicon-solar cells

*Arne Nylandsted Larsen + the PLATOS Project**
Department of Physics and Astronomy/iNANO, Aarhus University

The small absorption coefficient in silicon of light in the red to near infrared region is an inherent problem in Si thin-film solar cells resulting in poor efficiencies. Exploiting the special scattering abilities of localized surface-plasmon resonances in metallic nanoparticles has recently received much attention as a means to increase the energy conversion in thin-film solar cells. We are presently investigating the use of Al nanoparticles on top of a Si solar cell to improve the photo-current response. Results from this investigation will be presented together with a general introduction to the field of light-trapping in solar cells.

* The PLATOS Project (Localized-surface plasmons and silicon thin-film solar cells) is an Aalborg University-Aarhus University collaboration financed by the VILLUM Foundation

Bringing the infrared to light

Jeppe Seidelin Dam, Peter Tidemand-Lichtenberg and Christian Pedersen, DTU Fotonik

Infrared imaging is usually done by use of infrared cameras. We present an effective alternative approach where infrared light is converted to near visible light in a non-linear process, and then detected by low cost, high performance camera. The approach is generic and can be applied towards many different applications.

Parametric down conversion in an ultra-cold atomic gas

Jan Arlt, Department of Physics and Astronomy, Aarhus University, Ny Munkegade Building 1520, 8000 Aarhus C

Nonlinear processes in ultra-cold quantum gasses can closely mimic many other quantum systems. In particular the spin conversion process in a Bose-Einstein condensate can be understood in terms of parametric down conversion. In my presentation I will show the correspondence between the two systems, and describe parametric amplification in spinor gasses. Moreover I will show the amplification of vacuum fluctuations in this matter wave system and outline the strategy for creating non-classical states of matter waves.

Compact optical design solutions using focus tunable lenses

Mark Blum, Chief Operating Officer, Optotune, Switzerland

Several approaches have been demonstrated to build focus tunable lenses. The additional degree of freedom enables the design of elegant, compact optical systems, typically with less mechanics. We present a new range of electrically and mechanically focus tunable lenses of different sizes and tuning ranges and discuss their characteristics. We show how tunable lenses can be used to improve optical design for auto-focus and zoom in terms of size, quality and speed. Furthermore, we present an LED-based spot light with variable illumination angle, which shows optimal performance in terms of spot quality and optical efficiency.

A new approach to low loss photonic crystal waveguides

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Photonic crystal waveguides allow ultra-compact realization of integrated optical components because they have high group index. However, they also induce significant losses in effect reducing the scope of their applications. We find that by increasing the photonic crystal hole to pitch ratio r/Λ to 0.388 a low loss transmission band is created below the traditional photonic crystal guiding band. Furthermore this low loss band has sharply defined cutoffs transmission edges for devices with a length of 50 μm or longer. Finite difference time domain and plane wave expansion simulations confirm the results and show that the sharpness of the cutoffs can be explained by the spectral shape of the guiding mode in the band diagram.

The interaction of ultra-short laser pulses with materials.

Peter Balling, Martin S. Christensen, Martin Frislev, Henrik Dueholm Hansen,

Lauge Andreas Kjær, Lasse Refsgaard, Juha-Matti Savolainen, Kristian J. Wædegaard, Timo Zeyer

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Pulsed lasers are extremely useful tools for precision processing. The ongoing development of laser technology continues to expand the range of laser parameters that are available. This means that for a specific process targeted, one will eventually be able to choose a laser with a certain wavelength, pulse duration, repetition rate, and average power.

In this presentation, it will be discussed how it is possible to obtain guidance in choosing these parameters by developing simple models for the material response that are conferred against experimental measurements.

For metals, the material response is modeled numerically within the so-called two-temperature model [1,2,3]. The outcome is strongly influenced by a relatively high thermal conductivity. For instance, this means that the achievable resolution is dependent on the laser pulse duration, but also on the applied laser fluence.

Dielectrics can be processed with light of sufficiently high photon energy to bridge the band gap. They can, however, also be treated with lasers with a sufficiently short pulse duration, since the excitation can in this case proceed by non-linear absorption of the light. This may be useful for precision surface structuring and in addition opens the possibility of volume modifications.

We will present recent results from numerical modeling of dielectric materials [4,5]. The modeling, which is based on extensions of the so-called multiple-rate equation [6], is compared with experimental results.

The talk will include several examples of laser processing from our group encompassing both fundamental investigations of light-matter interactions as well as applications within micro-mechanical interlocking, fiber-grating writing, and laser-written holography.

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Local coherent excitation of surface plasmon polaritons by linear- and non-linear scattering off organic nanofibers

Esben Skovsen, Department of Physics and Nanotechnology, Aalborg University, Denmark

With the recent rapid development within the field of plasmonics, the need for practical and efficient local sources for exciting surface plasmon polaritons (SPPs) has increased. The classic prism based excitation schemes are bulky and somewhat impractical for many applications and alternative methods based on e.g. quantum dot luminescence are non-coherent and have limited tunability. Therefore development of alternative methods for local, coherent and tunable surface plasmon excitation would be desirable. One well documented alternative is to use so called grating couplers, where a series of parallel of dielectric ridges deposited on a metal surface are used to scatter light and allow for SPP excitation. Inspired by this we have investigated if light scattering by aligned organic nanofibers on a smooth metal surface can be used for SPP excitation in a similar manner. Using angle resolved leakage radiation spectroscopy we have demonstrated that linear scattering of light by aligned organic nanofibers deposited on a smooth metal surface can efficiently excite SPPs. In addition, using organic nanofibers with a second-order optical non-linearity, we have also demonstrated that it is possible to use the combined effect of second-harmonic generation (SHG) in the nanofibers and subsequent scattering to excite SPPs at the second-harmonic frequency of the excitation light.

Advances in DUV spectroscopy

Preben Buchhave[1], Peter Tidemand-Lichtenberg[2] and Claus Tilsted Mogensen[3]

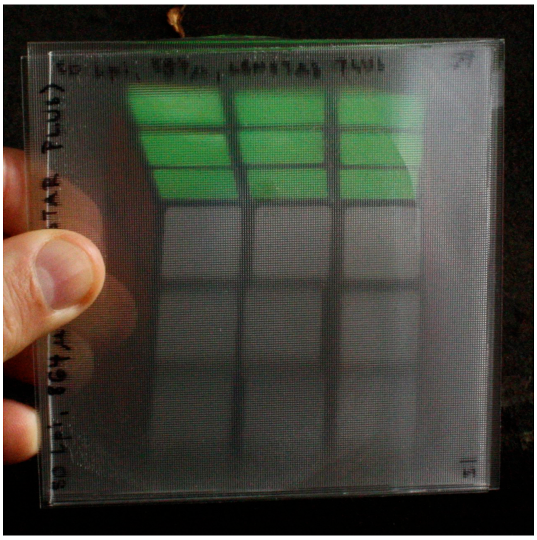
[1]: Intarsia Optics I/S, [2]: DTU Fotonik, [3]: Grundfos Management Center

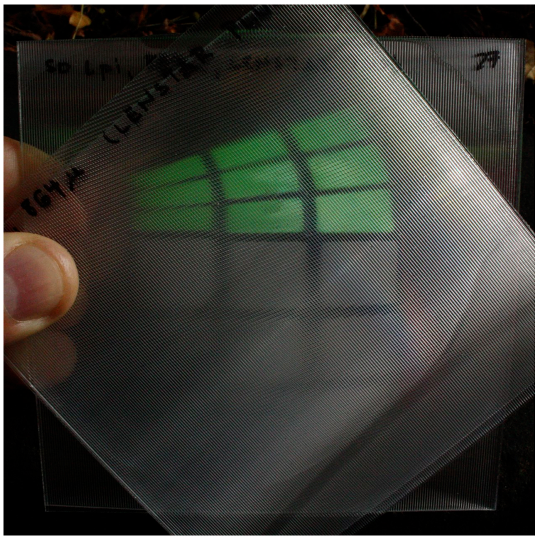
The would-be advantages of deep UV (DUV) spectroscopy are well known, but the potential applications have so far not been fully realized due to technological limitations and, perhaps, lack of bright ideas. However, new components and new knowledge about DUV spectra and spectroscopic methods combined with increasing needs for solutions to practical problems in environmental protection, medicine and pollution monitoring promise a new era in DUV spectroscopy. Here we shall review the basis for DUV spectroscopy, both DUV fluorescence and DUV Raman spectroscopy, and describe recent advances in technology and principles that could be applied to new and improved applications of this promising technique. As an example we describe a recent cooperation between Grundfos, DTU and Intarsia Optics to measure live bacterial cells in drinking water.

Optical vortices in a new light

Johannes Courtial, Lecturer, University of Glasgow, School of Physics and Astronomy

Certain light-ray fields are forbidden by wave optics, but can still be created, in slightly compromised form, with windows called METATOYs. The compromise is pixellation, but as long as the individual pixels cannot be resolved, i.e. by viewing the METATOY from a suitable viewing distance, this compromise is invisible and METATOYs appear to be wave-optically forbidden windows. The forbidden fields contain a non-zero vortex-charge density at every point, which means the fields can only be completely dark. METATOYs collect the vortex-charge density along the edge of the pixels, which means the rest of the beam can be bright. This opens up new possibilities in optical-instrument design.





In this talk I will concentrate on METATOYs that rotate the light-ray direction around the local window normal. Such windows can be elegantly described in terms of complex ray-optical refractive-index interfaces (we call the refractive index "ray-optical" to differentiate it from standard refractive index, which implies absorption for complex values; for real values, the two definitions agree). I will describe recent experimental demonstrations of such windows (see the pictures, which show a Rubik's cube seen through METATOYs that rotate the light-ray direction through different angles, namely 90° and 180°). METATOYs can be great fun, but it is now time to take them seriously!

Posters

Single molecule FRET microscopy studies of G-quadruplex DNA structures

Sofie Louise Kragh, iNANO, Aarhus University, Ny Munkegade Building 1521, 8000 Aarhus C

Telomeric DNA is mostly double-stranded but ends up with a G-rich single stand overhang which can form G-quadruplex structure. Previous studies have established that human telomeric DNA sequences containing four canonical TTAGGG repeats can adopt several different G-quadruplex structures that may coexist with each other. [1] Studies have shown that sequences containing four human telometric variant CTAGGG repeats, adopts a novel antiparallel G-quadruplex. [2] We investigate the two different telomeric DNA sequences with single molecule Fluorescence Resonance Energy Transfer (FRET).

Bio-optofluidics and Bio-photonics: Programmable Phase Optics activities at DTU Fotonik

Andrew Bañas, Darwin Palima, Finn Pedersen and Jesper Glückstad, Department of Photonics Engineering, DTU, Ørsted Plads,2800 Kgs. Lyngby

We present ongoing research and development activities for constructing a compact next generation BioPhotonics Workstation and a Bio-optofluidic Cell Sorter (cell-BOCS) for all-optical micro-manipulation platforms utilizing low numerical aperture beam geometries. Unlike conventional high NA optical tweezers, the BioPhotonics workstation is e.g. capable of long range 3D manipulation. This enables a variety of biological studies such as manipulation of intricate micro-fabricated assemblies or for automated and parallel optofluidic cell sorting. To further reduce its overhead, we propose ways of making the BioPhotonics Workstation platform more photon efficient by studying the 3D distribution of the counter propagating beams and utilizing the Generalized Phase Contrast (GPC) method for illuminating the applied spatial light modulators.

Efficiency enhancement in organic solar cells by controlled nanostructuring

Roana Melina de Oliveira Hansen, Michal Radziwon, Morten Madsen and Horst-Günter Rubahn, University of Southern Denmark, Alsion, Sønderborg

The tremendous progress made within organic solar cell technology has made it a promising source for renewable energy offering both low cost and remarkable integration flexibility. Although organic solar cells today has reached efficiencies above 8% both for polymer and small molecule cells, their efficiency is still low compared to their inorganic counterparts which remain as a bottleneck towards their commercialization. Here we focus on two methods for increasing the efficiency of organic solar cells by adding and controlling nanoscale structures in the cell in order to achieve both an optimum charge generation and provide efficient transport of the generated charge carriers to the electrodes.

In order to increase the optical path length of the incident light in the thin-film (addressing the light absorption issue), we have fabricated inverted bulk-heterojunction solar cells containing diffraction gratings on the bottom-electrode, which trap the incident light into the active layer and enhance the device efficiency. A P3HT:PCBM molecular blend was used as the solar cell active layer and the gratings were respectively tuned to couple light at the same wavelength as the film absorption peak (500 nm), thereby enhancing the solar cell efficiency. Our results confirm an enhancement of about 30% on the conversion efficiency for the cells containing diffraction gratings.

Furthermore, we aim at controlling the nanoscale morphology within the active layer in order to optimize for both exciton dissociation and charge transport at the same time and thus decrease charge-trap densities compared to bulk-heterojunctions. Our study is focused on growth of crystalline P-type nanostructures from physical vapor deposition combined with a fullerene based N-type semiconductor. Here, we aim at investigating the effect from different cell architectures with the heterojunction interface varying from being completely flat (bilayer) to possess nanostructures of different sizes. This method brings a deeper understanding of the effects from different interface morphologies which influence the solar cells device performances.

Femtosecond laser ablation of dielectrics: Experiments and modeling

Kristian Wædegaard, Lauge Kjær, Martin Frislev and Peter Balling, Department of Physics and Astronomy, Aarhus University, Ny Munkegade Building 1520, 8000 Aarhus C

Sapphire (0001) is used in an investigation of ablation of dielectrics. In order to test a new model for ultra-fast light-matter interaction, holes from single-shot ablation are investigated by looking at the relation between ablation depth and laser pulse energy and at transient optical properties.

Characterization of localized field enhancements in laser fabricated gold needle nanostructures

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Field intensity enhancements (FE) produced by gold needle nanostructures, viz., standing upright sharp and sphere-terminated needles, fabricated on a gold substrate by femtosecond laser irradiation are investigated and characterized using linear reflection spectroscopy, two-photon photoluminescence (TPL) scanning optical microscopy, and high-resolution confocal Raman microscopy. Surface enhanced Raman scattering (SERS) is observed with linearly polarized excitation at the pump wavelength of 532 nm of Rhodamine 6G (R6G) homogenously adsorbed on the structures. The obtained high-resolution TPL and Raman images both indicate a relatively high FE level of ~75 for the fabricated structures. We believe that the observed FE levels along with the special topography make these upright elongated structures to be particularly promising for SERS experiments with living cells.

Dispersion of strongly confined channel plasmon polariton modes

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We report on experimental (by use of scanning near-field optical microscopy) and theoretical investigations of strongly confined (~λ/5) channel plasmon polariton (CPP) modes propagating at telecom wavelengths (1425-1630 nm) along V-grooves cut in a gold film. The main CPP

characteristics (mode index, width and propagation length) are determined directly from the experimental near-field images and compared to theoretical results obtained using an analytic description of CPP modes supported by (infinitely deep) V-grooves and finite-element simulations implemented in COMSOL.

Three-dimensional Radiation Dosimetry using Optical CT

Thomas Kinnari, Department of Physics and Astronomy, Aarhus University, Ny Munkegade Building 1520, 8000 Aarhus C

Modern Radiotherapy techniques demand dose verification in three dimensions. Radiation sensitive gel dosimeters are capable of recording a true 3-D dose distribution. Optical Computed Tomography (OCT) is an imaging technique used to reconstruct images from scanned gel dosimeters. Light transmitted through the gel is recorded as a function of the spatial coordinates and reconstructed to a final 3-D dose map. The use of OCT in 3-D radiation dosimetry is superior to magnetic resonance imaging (MRI) in costs, availability, increased scan speed, and resolution.

Controlling the refractive index of optical fibers by short-pulse materials processing

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Traditionally one uses UV-light to change the refractive index of optical fibers. Recently, it has been shown that similar effects can be obtained with ultra-short laser pulses. However, the latter allows a greater spatial resolution, and we present a setup for writing complex refractive-index patterns into an optical fiber. Furthermore, we are developing a method based on measuring the far field profile of the light from an optical fiber to quantify the refractive index changes.

Direct laser-written holograms using ultra-short laser pulses

Henrik Dueholm Hansen, Kristian Juncher Wædegaard and Peter Balling, Department of Physics and Astronomy, Aarhus University, Ny Munkegade Building 1520, Denmark

A binary hologram can be written directly on a reflective or a transparent material with an infrared femtosecond laser beam. The hologram image can be reconstructed in either the transmission and/or reflection with a standard laser pointer. By using short-pulse laser ablation, unique holograms with a resolution of 111kpixels/mm^2 can be manufactured. We have written holograms on various surfaces and built in 3D effects. The holograms are presently being characterized and optimized for efficiency and resolution. Practical applications for security and anti-counterfeiting will be briefly discussed.

Understanding short-pulse laser ablation of metals

Martin S. Christensen, Juha-Matti Savolainen, Timo Zeyer and Peter Balling, Department of Physics and Astronomy, Aarhus University, Ny Munkegade Building 1520, Denmark

The interaction between ultra-short laser pulses and metal surfaces is of fundamental as well as of practical interest. We will present a recent experimental study of the mechanism of ultra-short-pulse laser ablation of aluminum and silver. The results will be compared to two different kinds of numerical simulations: a simple thermodynamical approach, and a more rigorous Molecular-Dynamics model. Finally, we present a new experiment for measuring the change of the optical properties of a metal surface following repeated ultra-short-pulse laser ablation.