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Book of abstracts

Oral presentations

Differential dynamic microscopy: A novel tool for food science?

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In this lecture I will describe a recently introduced dynamic microscopy method for the investigation of soft matter samples. The method, named Differential Dynamic Microscopy (DDM), allows to extract scattering information from imaging experiments, bridging the gap between these two complementary experimental domains. DDM is a quite flexible tool since it can be used for example in combination with bright-field, phase contrast, confocal and depolarized microscopy. Recent experimental results on soft materials will be presented. Possible applications in food science will be also discussed.

Spectral imaging for food applications

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Within the newly formed Center for Imaging Food Quality (CIFQ) a range of spectral imaging techniques are being developed and tested for food applications. This presentation will illustrate the current methodology and results. Targets are surface chemistry mapping and subsurface laser scattering assessment.

NIR spectrometers used for food analysis

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In this presentation we will describe how Near-Infrared Spectroscopy is used to analyse food quality and perform process optimization in the food industry . The basic theory behind the measusements and data analysis required will be presented and compared to IR spectroscopy. Furthermore, the key requirements and challenges for the optical system - today as well as in the future - will be described.

In-Situ, Non-Destructive Control Of Food Quality Using Raman Spectroscopy And Multivariate Analysis

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In recent years there has been an increasing focus from the consumers on food quality i.e. unwanted substances such as bacteria, pesticides and drug residues, food composition and additives1. This is also reflected in increasing interest for organic food products. It seems therefore appropriate to develop substance specific, non-destructive and fast measuring techniques that can be used close to the consumer, for monitoring different properties of food products. In the present paper a step is taken towards the development of an in-situ measuring technique for discriminating between different components in commercial, animal flesh products. Multivariate analysis applied to Raman data offers the opportunity to elucidate very small differences in the chemical composition of different kinds of samples2. When all constituents of the samples are known it is possible to use a supervised classification method. In this paper Partial Least Squares Discriminant Analysis (PLS-DA)3 is used. Furthermore the data analysis can be improved by programming a flowchart containing multiple PLS-DA steps, where each step has a narrower task. By specifying what each new PLS-DA step has to investigate, one prevents the model from calculating what is already obvious and as a consequence the accuracy of the results is greatly improved. In the specific example considered below it has to be investigated whether or not it is possible to discover the presence of minced pork in a tub of minced lamb by applying PLS-DA to the Raman data obtained from meat and using the programmed flowchart shown in figure 1. The Raman spectra were measured directly on the tub, which was obtained from the local butcher. The Raman spectra can also be obtained by measuring through the protective film usually covering flesh products. The Raman spectra were measured in maps using a homebuilt microscope setup featuring 633nm excitation and Raman mapping abilities. As shown in figure 1 it is first investigated whether the data should be characterized as fat, meat or unknown. Secondly, it is investigated what kind of animal the fat, the meat and the unknown comes from.

Plasmon-based nanophotonics:
Fundamental issues and practical perspectives

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Recent years have seen an explosion of research into nanophotonics based on a special type of electromagnetic waves called surface plasmon-polaritons that can propagate along metal interfaces and be guided by metallic nanostructures beyond the diffraction limit of light typical for the conventional dielectric waveguides. This remarkable capability opens unique prospects for the design of highly integrated photonic signal-processing systems, nano-resolution optical imaging techniques and sensors. This talk reviews a number of fundamental issues within the area of sub-wavelength plasmonic waveguides and waveguide components [1-3], and discusses possibilities for immediate practical applications of, at least, some of plasmonic waveguiding configurations [4].

1. T. Ebbesen, C. Genet, and S. I. Bozhevolnyi, *Surface-plasmon circuitry*, Phys. Today **61**, 44 (May 2008).
2. *Plasmonic Nanoguides and Circuits*, S. I. Bozhevolnyi, ed. (Pan Stanford, 2009).
3. D. K. Gramotnev and S. I. Bozhevolnyi, *Plasmonics beyond the diffraction limit*, Nature Photonics **4**, 83 (2010).
4. http://www.ict-platon.eu/

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Controlling the Coupling of Nitrogen Vacancy Centers to a Silver Nanowire

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Dipole emitters are expected to efficiently couple to the plasmonic mode propagating along a cylindrically shaped metallic nano-structure [1]. Such a strongly coupled system could serve as a fundamental building block for a single photon source on demand and a device enabling strong non-linear interaction at the level of a few photons [2]. In our contribution we demonstrate the controlled coupling of a nitrogen vacancy centers in a diamond nano-crystal to a plasmonic nano-structure. This is in contrast to previous realizations, where the nanowire - dipole systems were assembled randomly. We achieve control over the relative nanowire diamond nano-crystal position by using an atomic force microscope (AFM) in contact mode operation. Mono-crystalline silver nano-wires were fabricated by a polyol reduction process of silver nitride. The resulting nanowires were together with the nano-diamonds spin coated on a fused silica substrate. Fig. 1 (a) shows an AFM image of a silver nanowire and a nano-diamond. This particular nano-diamond contained nitrogen-vacancy defects, which are characterized by an emission lifetime of around 12.1 ns, as shown by the black dots in Fig. 1 (b).

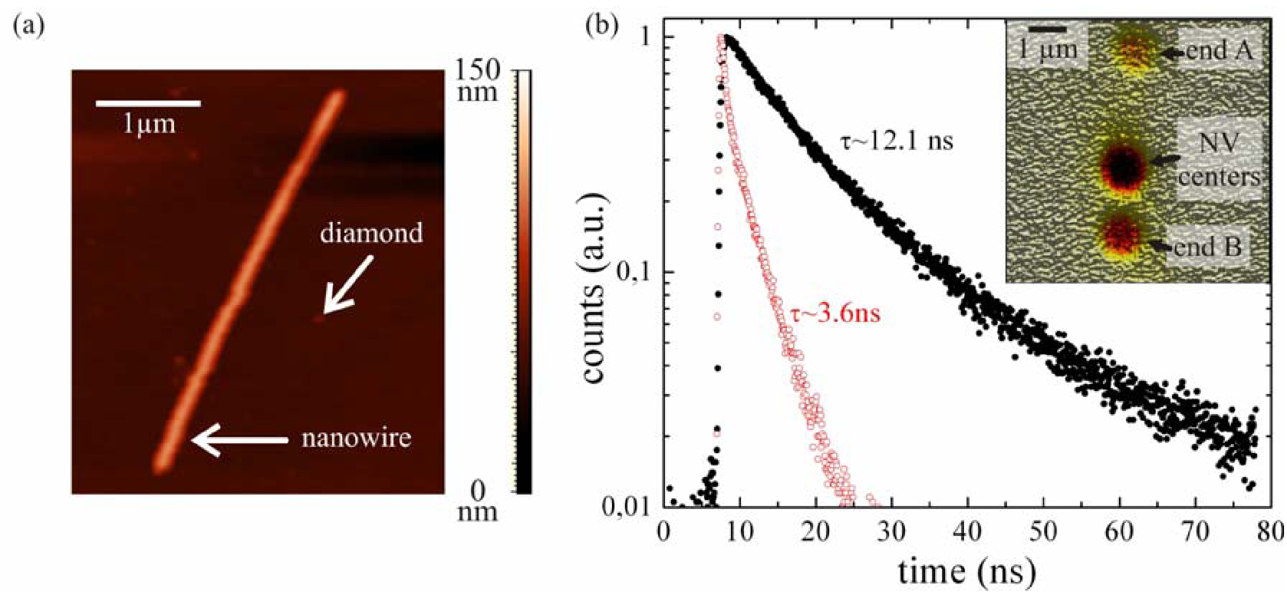

Fig. 1: (a) AFM image of the investigated silver nanowire and the nano-diamond taken before the diamond has been moved in the near vicinity of the wire. (b) Lifetime, τ, measurements of uncoupled (black dots) and coupled (red circles) NV-centers. Inset: fluorescence image of the coupled NV-center nanowire system.

After its characterization, this nano-crystal has been brought into the near vicinity of the silver nano-wire by pushing the diamond with the AFM cantilever. As a direct consequence of the coupling to the plasmonic mode the emitter lifetime decreased by a factor of 3.4. This is shown by the red dots in Fig. 1 (b). The excitation of propagating surface plasmons could be verified by observing light re-emission from the nano-wire end faces, as shown by the inset of Fig. 1 (b).

References

[1] D. E. Chang et al., *Quantum optics with surface plasmons*, Phys. Rev. Lett. **97**, 053002 (2006).
[2] D. E. Chang et al., *A single photon transistor using nanoscale surface plasmons*, Nature Physics 3, 807-812 (2007).

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Holey-structured metamatials make perfect endoscopes

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The resolution of imaging using conventional optics is limited by diffraction. When a lens is used to construct an image, e.g. by means of a camera, the fine details disappear. Due to the fundamental diffraction limit, features smaller than approximately the wavelength of light become lost. This is because the light that carries the fine details has high spatial frequencies, i.e. they are evanescent waves that decay exponentially away from the image source. The idea of a super (or perfect) lens which can construct an image on the sub-wavelength scale is attractive both from an application and a theoretical point of view, and has been a dream for lens makers for many years. Such a superlens must be able, not only to cancel the phase delay of propagating waves, but also to exponentially enhance the evanescent waves. This is possible using a left-handed slab with a negative refractive index of -1, i.e., a material that both have $\mu = -1$ and $\varepsilon = -1$. This was shown by Sir John Pendry 10 years ago. Pendry furthermore showed that in the electrostatic limit, where the two polarizations become decoupled, superlensing can be achieved with a material having only $\varepsilon = -1$, i.e., using a metal slab at the surface plasmon resonance frequency. This has subsequently been verified by experiments.

In this talk we will give a short introduction to superlensing and the perfect lens. Following the introduction we will focus on superlensing properties of holey metal films. We will analyze whether the superlensing effect can be transformed to lower frequencies by taking advantage of the so-called spoof surface plasmons. These surface electromagnetic modes emerge when a perfect conductor film is perforated with a periodic array of apertures and have similar characteristics to canonical surface plasmons. We will demonstrate that, contrary to the aforementioned expectations, superlensing effects do not appear in holey metal films. Instead, these structures can operate as perfect endoscopes, i.e., transmit all incident plane waves (propagating and evanescent) with unit efficiency at some resonant frequencies [1-2]. In the last part of the talk we will introduce a holey-structured material for acoustic deep-sub-wavelength imaging. We will show that the physics of the acoustic endoscope is similar to the optical endoscope and an experimental verification of the endoscope effect will be presented [3].

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[3] J. Zhu, J. Christensen, J. Jung, L. Martín-Moreno, X. Yin, L. Lok, X. Zhang, and F.J. García-Vidal, Accepted for publication in Nature Phys. (2010)

Guidelines for 1D-periodic surface microstructures for antireflective lenses

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Abstract: Antireflective properties of one-dimensional periodically microstructured lens surfaces (refractive index 1.5) are studied with the Green's function surface integral equation method, and design guidelines are obtained. Special attention is given to the requirement of having practically all incident light transmitted in the fundamental transmission diffraction order. The effect of the presence of higher transmission diffraction orders is studied to determine if such more easily fabricated structures will be useful. The decrease of optimum fill factor of a periodic array of subwavelength ridges with structure period is explained as a waveguiding effect. Near-fields are calculated illustrating standing-wave interference and waveguiding effects for ridge structures, and adiabatic field transformation for tapered structures, including evanescent near-fields in in- and out-coupling regions. The antireflective properties of tapered geometries are considered for a wide range of angles of light incidence. It is found that while the reflection can be very small this rarely implies high transmission into the fundamental transmission diffraction order when higher-order transmission diffraction orders exist. This leads to the guideline that for visible and normally incident light the surface structure period should not be larger than ~ 300 nm, and a smaller period is needed in the case of oblique light incidence.

Infrared supercontinuum for seeing the invisible

Lasse Leick, Carsten L. Thomsen, NKT Photonics
Søren Keiding, Aarhus Universitet
Ole Bang, DTU Fotonik

Light plays a crucial role in solving today's main scientific and medical challenges. The molecules that define a disease, pollution or an impurity in a food sample all have a characteristic optical fingerprint, which can be read by detecting the infrared light that the sample absorbs. NKT Photonics have over the last five years build up a leading position within visible light supercontinuum sources for analysis of biological samples. Now NKT Photonics will together with researchers from the Technical University of Denmark and the University of Aarhus develop a new generation of lasers that have the same extreme bandwidth but cover the near infrared range from 2 to 5 µm. Such a laser does not exist today, but it would have vast potential within areas as diverse as biomedical applications, homeland security, process control and atmospheric LIDAR.

Measuring ionising radiation with fibre-coupled organic scintillators

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This presentation will pertain to the use of so-called organic scintillators for detecting ionising radiation by a physical process known as radioluminescence. In particular organic scintillators coupled to optical fibres will be the subject of the presentation; as such detection systems offer a very convenient method of detecting ionising radiation during radiation therapy.

The presentation will focus on the optical properties of the fibre materials and the organic scintillator materials used in these sensors. Furthermore, the light generating process in the scintillators as well as fabrication methods will be discussed.

Spectroscopy of macromolecular ions in vacuo

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The electronic structure of a chromophore (i.e., light absorber) is strongly perturbed by its surrounding environment, e.g., water. To reveal the intrinsic electronic properties, it is therefore necessary to study isolated molecules in vacuo. Many important chromophores are ionic, which renders experiments complicated as it is not possible to produce enough absorbing species for traditional light transmission spectroscopy. In Aarhus we have developed state-of-the-art apparatus to record gas-phase absorption spectra of macromolecular ions. The technique is based on the combination of an electrospray ion source, a multipole ion trap for pre-storage, an electrostatic ion storage ring, and pulsed tuneable lasers and relies on measurements of the delayed dissociation of photoexcited ions (action spectroscopy). I will present some of our recent results for chromophores of relevance in materials science and photobiology and discuss how the transition energies depend on the spatial delocalization of the pi electrons, the character of the electronic transition, nearby charges, and, solvation by polar molecules. Finally, our spectra provide a natural testing ground for future quantum chemical theories and methods.

Ultrafast fluorescence lifetime imaging - for cell biology, high content analysis and label-free diagnosis

Paul French
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This talk will review our development and application of ultrafast multidimensional fluorescence imaging (MDFI) technology, with an emphasis on fluorescence lifetime imaging (FLIM) applied to microscopy, endoscopy and tomography. Using fluorescent labels, FLIM and Forster resonant energy transfer (FRET) can provide readouts of variations in the local molecular environment of labelled proteins (e.g. calcium transients) and of protein-protein interactions. To study cell signalling networks and mechanisms of disease, we have developed a range of microscopes ranging from stimulated emission depletion (STED) FLIM microscopy to study spatial phenomena with super resolution through to multibeam multiphoton FLIM microscopy to map changes in metabolic pathways using cellular autofluorescence. For faster and more systematic investigations, we have developed an automated high-speed optically-sectioned FLIM multiwell plate reader to read out, e.g. membrane properties and protein interactions via FRET in fixed and live cells. For drug discovery and fundamental biomedical research, it is important to translate cell-based experiments to in vivo studies. Accordingly, we are developing tomographic FLIM instruments based on optical projection tomography for transparent/optically cleared samples such as zebrafish and diffuse fluorescence molecular tomography for mouse imaging. For clinical applications, FLIM and MDFI can be applied to autofluorescence to provide label-free molecular contrast in biological tissue and is being investigated for ex vivo and in vivo imaging with a view to developing diagnostic tools. To this end we have developed a FLIM microconfocal endoscope and a multispectral multiphoton FLIM microscope based on the DermaInspect platform. We have also developed a range of single point multidimensional fluorometers to provide information on complex spectro-temporal signals to complement the MDFI modalities.

Back-Scattering Interferometry – label-free biosensing

Henrik Schiøtt Sørensen, Meijie Li, Thomas Martini Jørgensen, Peter E Andersen
DTU Fotonik

Back Scattering Interferometry (BSI) has been used to monitor biochemical reactions in very dilute samples. This has been done label-free and in free-solution in picoliter sample volumes. BSI is a measurement technique based on light interacting with a microfluidic channel. In this method the physical variable being measured is the change in refractive index with time, which can be caused by bulk properties or solute interactions. The unique optical train employed in BSI allows near real-time quantification of solutes at attomole levels and within detection volumes of tens of picoliters.

To summarize, BSI has the highest figure of merit among candidate detection schemes when considering the combination of sample volume, time, sensitivity, cost, and system simplicity for doing label–free, in solution protein–protein interaction studies. The capacity to measure basically any circulating disease marker or mediator in blood samples can give rise to numerous applications within the clinical arena. In addition, the BSI technique has the potential to be applied to other areas investigation where it is desirable to analyze small volumes of liquid samples, including drug discovery and environmental monitoring.

Analyte focusing at self assembling hotspots for SERS by leaning silver coated silicon nanopillars

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Currently, the widespread use of surface enhanced Raman scattering (SERS) systems has been limited by the inability to produce reproducible SERS active substrates with sufficient Raman enhancement. Using a simple maskless fabrication method we show how freestanding high aspect ratio silicon nanopillars covered with silver can be produced over large areas in a highly reproducible cleanroom process. After being exposed to the analyte in the gas phase a droplet of water or other solvent is deposited onto the substrate. As the solvent evaporates, surface tension will cause the nanopillars to lean towards their nearest neighbours thus creating self assembled electromagnetic "hot spots". Analyte molecules adsorbed at the tips of the pillars will now be located exactly in the "hot spots" as the pillars lean together. This leaning / analyte focusing mechanism creates an enormous number of "hot spots" inside the laser excitation area, drastically increasing the Raman signal compared to non-leaning pillars. Furthermore, the large enhancement of the Raman signal is reproduced uniformly across the wafer. Using these substrates we demonstrate the capability to detect trace amounts of explosives in the gas phase (for landmine clearance) and pesticide remnants in the liquid phase (environmental monitoring). Being a solid substrate this material is very practical to use and can be applied in current Raman systems. As the fabrication method is low cost and reproducible over large areas (wafer scale), we believe that these substrates will enable SERS to become more applicable in the field of chemical sensing.

Recent developments in laser diagnostics of combustion processes

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Different laser diagnostic techniques have during the last decade become very important tools in understanding phenomena related to combustion and high temperature reaction phenomena. The main advantages are the non-intrusivness in combination with high spatial and temporal resolution with the possibility to measure species concentrations, temperatures, velocities and surface/particle characteristics. The talk will be direted towards some recent developments and applications of various laser spectroscopic techniques, e.g. laser-induced fluorescence, polarisation spectroscopy and thermographic phosphors as well as challenges like measurements in areas with limited optical access, e.g furnaces, and in optical dense media, e.g. sprays.

Optical combustion diagnostics on a large two-stroke marine Diesel engine

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Large two-stroke Diesel engines offer several challenges to successful implementation of the type of optical and laser based measurement techniques which have been applied with so much success in smaller automotive engines. Here we present the first steps taken towards optical diagnostics in a full sized two-stroke Diesel engine for marine application. Optical ports, fitted with sapphire windows, have been developed, which allow normal uninterrupted engine operation over several hours. The evolution and movement of burning fuel clouds have been visualized at high framing rates (18 kHz) using a high-speed CMOS camera. From such image sequences individual flame ignition and propagation events can be followed in a cycle-resolved fashion. Through the use of high-speed two-colour pyrometry the temperature of the soot in the flame envelope can furthermore be visualized during the engine cycle. Finally, future implementations of laser based imaging techniques will be presented.

A multichannel spectroscopic system for simultaneous gas temperature measurements from several lines of sight

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The aim of the work is to develop a multichannel spectroscopic system for simultaneous gas temperature measurements from three lines of sight. Knowledge about the temperature from several lines of sight is greatly important for a more comprehensive combustion diagnostics.
The system is described and analyzed. Gas temperature measurement method applied in this work has been validated using the lab burner with known temperature profile. The accuracy of the method has been found to be within 4%.
The system has been applied on the exhaust duct of a test ship diesel engine. Temperatures as functions of time at 119 Hz have been obtained for the three ports on the exhaust duct. The results have shown the importance of simultaneous temperature measurements.
The system is being developed further towards the technique of tomographic reconstruction of cross-sectional temperature and species concentration distributions.

LED’s in Entertainment Lighting

Dennis Thykjær Jørgensen
Martin Professional A/S

The rapid progress in semiconductor technology over the last decades has lead to LEDs that now match discharge lamps in efficacy. In spite of this, LED’s are not just a one to one replacement. The power per LED is typically still very low compared to the 150W of the smallest discharge lamp used by Martin. Therefore, to reach the required luminance and colour of the delivered beam, the radiation from several (individually coloured) diodes has to be mixed, combined and delivered in the gate. The presentation will give a short introduction to Martin and the current use of LED technology in various products. After that the focus will be on the High Technology Foundation project Intelligent LED (InLED) where new principles for LED based light engines have been developed. Considerations about choice of LED, Lumen and Etendue, white diodes versus RGB etc will be discussed. Elements of the illumination design of the now commercial product MAC350 will be presented.