Fysikermøtet 2023

Abstracts for presentasjoner under Optikk

Abstracts for presentations at the strand for Optics

Sted: Konferanserom C, VilVite

Fredag 11.august kl.0900-1110

10:00 Florian Ströhl, UiT

New Methods for 3D Microscopy

Fluorescence microscopy of cellular processes should be performed in cells residing in their native environment and thus imaging should cover all dimensions of space and time. Yet, many studies rely on 2D imaging or 3D confocal microscopy, which is slow and phototoxic and thus has limited live-cell compatibility.

Light-sheet microscopy (LSM) may be the solution. Here, two objectives are oriented at right angles towards the sample. The first objective produces a thin sheet of light that excites fluorophores only within the focal plane of the second objective. It thus avoids the generation of out-of-focus light and reduces photodamage to a minimum. Scanning the sample through the imaged plane enables optically sectioned volumetric microscopy. Crucially though, the requirement of two objective lenses near the sample has the drawback of obstructing conventional sample mounting and has hence hindered a more widespread use of LSM in high-resolution microscopy.

To alleviate this drawback, we developed new LSM approaches that use only one objective for illumination and detection. Thus, the microscope is fully compatible with conventional sample mounting. I will highlight technical details on how we manage to align the focal plane of the objective with the illumination plane - a dedicated optical system downstream of the primary objective and hidden from the user - to rearrange the sample volume such that it can be recorded by a camera without optical aberrations.

10:20 <u>Md Rabiul Hasan</u>, Mathias N. Jensen, Jehona Salaj and Olav Gaute Hellesø, UiT

Photonic chips for optical trapping and Raman spectroscopy

Optical tweezers can be combined with Raman spectroscopy to characterise the chemical composition of microparticles. However, for nanoparticles, the diffraction limited laser spot used by optical tweezers is not suitable. We are thus investigating photonic chips to concentrate light below the diffraction limit for this application, and also to make it possible to do the characterise many particles in parallel.

We are investigating two approaches, the use of optical metasurfaces with quasi-bound states in the continuum (quasi-BIC) and trenches across optical waveguides. Both approaches will be described and some preliminary results shown. The main problem for Raman spectroscopy is that the signal is very weak, and it is thus important to keep noise at an even lower level. For both approaches, Raman scattering from the material (quasi-BIC or waveguide) will constitute the main noise, and we take special measures to reduce this background noise.

10:40 <u>Roman Zakoldae[1]</u>, Jehona Salaj[1], Marek Vlk[1], Henock. D. Yallew[1], S. Alberti[1], Jens Høvik[2], Astrid Aksnes[2], and Jana Jágerská[1]

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Mid-infrared spectroscopy on-chip with sub-ppm detection level

Over the past decade, mid-infrared waveguide-based sensors have emerged as an attractive and promising way for chip-scale spectroscopy of target molecules such as CO2, CH4, N2O, etc. Their operation principle relies on strong light absorption at the rotational–vibrational resonance of the target molecules, enabling both high sensitivity and specificity of detection with little or no cross-interference. The sensors fabricated using CMOS fabrication process, hold great potential for mass production of chip-scale photonic devices. However, miniaturization poses challenges on sensor sensitivity as reducing the sensor size results in shorter optical interaction path lengths, thus increasing the detection limit. For example, current CO2 detection limit with on-chip waveguides correlates to 1000 ppm. This calls for developing novel interaction principles and more efficient waveguide designs to overcome these limitations and enhance sensor performance.

In this contribution, we will present our latest advances in the design and development of mid-infrared waveguide-based sensors, pushing their detection limits by several order of magnitudes compared to the state of the art. First, suspended waveguides with extraordinary evanescent field confinement will be presented, achieving a confinement factor 107 % and low propagation losses (3.2 dB/cm). This waveguide demonstrated a detection limit of 12 ppb for CO2 isotopes. Secondly, we demonstrate slotted SOI waveguides supported with input/output couplers designed for methane detection. The detection limit of CH4 gas measured with our on-chip device is for the first time below atmospheric background of 2 ppm. Lastly, we have combined the developed waveguides with a polymer coating doped with cryptophane. This nanoporous layer has already demonstrated the ability to pre-concentrate target molecules thereby enhancing sensor sensitivity.

Developed ideas offer valuable insights and practical solutions to contribute to the advancement of chip-scale spectroscopy, which is attractive in various applications such as environmental monitoring, biochemical reactions, and human health diagnostics.

11:00 Gard Momrak Selnesaunet, Marie Bøe Henriksen, Torbjørn Skauli, UiO

The full truth about "resolution": Imaging the point spread function of hyperspectral cameras using tomographic reconstruction

A hyperspectral camera records a detailed spectrum of the incoming light in each pixel and is more appropriately called an imaging spectrometer. A hyperspectral image, therefore, contains a multitude of spectra which are "fingerprints" of the materials present in different locations in the image. Spectroscopic analysis can then be applied to the data in each pixel to extract physical or chemical information. This builds on the basic assumption that for a given pixel, all wavelengths in the spectrum are recorded from the same area. In other words, their "point spread function" (PSF), the distribution of sensitivity for a given pixel, is assumed to be the same for all wavelengths. To characterize this important aspect of camera quality, we need to measure the shape of the PSF, which contains full information about the camera resolution. This motivates our development of a setup to measure the detailed shape of the PSF for different cameras. Measuring the PSF is not trivial, for a variety of practical reasons. Ideally, to map the PSF we would like to use a scanning, stable, broadband, point-sized light source infinitely far away but such sources do not fit in the lab. Instead, we use a back-illuminated slit to create a line source that is scanned over the pixel while recording images. The resulting data contain a peak in the pixel signal when the slit traverses the pixel. This signal is integrated along the source line and is thus a projection of the PSF onto the scan direction. By scanning the source in multiple directions, we obtain a set of projections. We can then do tomographic reconstruction using the Radon transform to determine the full 2D shape of the PSF. We show how this technique can be used to obtain the full truth about resolution for different cameras.

11:20 Børge Hamre and Arne S. Kristoffersen, UiB

Light scattering and absorption by atmospheric and oceanic particles – theory, natural optical phenomena, and satellite remote sensing

We give a brief introduction to the theory behind light scattering and absorption by particles in the atmosphere and ocean and use it to explain natural optical phenomena such as halos; coronas; color and polarization of clear and cloudy skies; as well as greenish-turquoise colors of Norwegian fjords and glacial meltwater. Finally, we show how the theory of light scattering and absorption can be applied in satellite remote sensing of the atmosphere and ocean.

11:40 J.C. Tinguely, I.S. Opstad, S. Acuña, L.E. Villegas-Hernández, V.K. Dubey, F. Ströhl, K. Agarwal, B.S. Ahluwalia, UiT

Integrated optical circuits for multimodal super-resolution microscopy

The evanescent field on the surface of photonic waveguides can be utilized for total internal reflection fluorescence (TIRF) imaging. Making use of high refractive index contrast materials such as Si3N4 or Ta2O5 on SiO2 can create high energy density fields of ca. 200 nm penetration depth at arbitrary excitation areas while being compatible as substrates for live cell imaging. Compared to conventional, objective-based TIRF microscopes, the chip-based approach offers easy multiplexing by adjustment-free switching of excitation wavelengths, large field-of-view imaging through decoupling of excitation and collection optics, telecom device compatibility for fast circuit switches, smaller footprint, among other advantages.

Beyond diffraction limited TIRF microscopy, different super-resolution techniques have been implemented on the chip platform. Chip-based direct stochastic optical reconstruction microscopy (dSTORM) demonstrated an extraordinary resolution of 75 nm over a field of view of 0.5 mm x 0.5 mm3. By shifting the interference fringes of multimode waveguides, the excitation intensity can be modulated for fluctuation-based techniques such as ESI, SOFI or MUSICAL. By using an array of counter propagating waveguides, chip-based structured illumination microscopy (SIM) has also been implemented. The high effective refractive index of the guided light (e.g., NA 1.7) offers higher spatial frequencies than possible with objective-based, far-field approaches, which push the achievable resolution beyond the possibilities of standard implementations as demonstrated for SIM (2.3-fold vs. regular 2-fold) or MUSICAL (2.2-3.6-fold against regular results).

Chip imaging has been utilized for different biological models such as liver sinusoidal endothelial cells or tissue sections, enabling correlative implementations with phase and electron microscopy. The developments so far should be seen as the first steps of this technology. There is much to be explored, with multimodality and retrofitting possibilities to conventional microscopes providing the potential towards a paradigm shift in super-resolution optical microscopy.