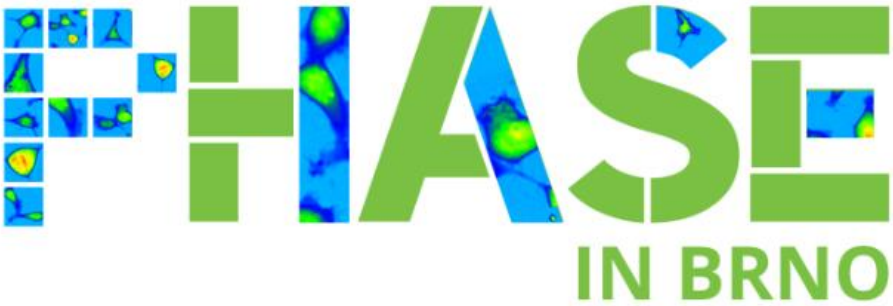
BRNO UNIVERSITY OF TECHNOLOGY

Central European Institute of Technology

4th International conference



BOOK OF ABSTRACTS

October 12-15, 2026

Brno, Czech Republic

Programme

Monday 12th October

15:30-18:00	Registration, CEITEC, Purkyňova 123, building S, ground floor
16:00-17:30	Tour around CEITEC BUT labs
18:00	*Welcome drink* Daniel Zicha - Opening speech

Tuesday 13th October

8:30-8:55	Registration
8:55	Radim Chmelík - Conference opening
	Morning lecture session – chaired by Radim Chmelík
9:00-10:00 KEYNOTE	Pierre Marquet: From Quantitative Phase Imaging to Neuropsychiatric Disorders: Twenty Years of Digital Holographic Microscopy
10:00-10:30	Xiaohui Ju**:** Nanorobot-Cell Communication via In Situ Generation of Biochemical Signals
	Coffee break
11:00-12:00 KEYNOTE	Małgorzata Kujawińska: Metrological characterization and validation of QPI systems in life sciences
12:00-12:30	Damian Suski: Reliable Uncertainty Quantification for Model-based Interferometric Metrology of Semiconductor Structures
	Lunch
	Afternoon lecture session – chaired by Daniel Zicha
14:00-14:30	Radim Chmelík: Holographic Incoherent-light-source Optical Diffraction Tomography: Optical Sections of Refractive-Index Structure
14:30-15:00	Václav Bočan: The scaling of cellular growth
16:00	Villa Tugendhat visit or First time in Brno tour

Wednesday 14th October

	Morning lecture session – chaired by Aneta Křížová
9:00-10:00 KEYNOTE	Björn Kemper: Digital Holographic Microscopy for Cytometry and Histology
10:00-10:30	Emmanouela Filippidi: Enrichment of higher charge density subspecies of random polyelectrolyte copolymer in complex coacervate
	Coffee break
11:00-12:00 KEYNOTE	Maciej Trusiak: Computational lensless holographic imaging from deep-UV to near-IR on a standard sensor
12:00-12:30	Julianna Winnik: Polarization Diffraction Grating-Based Shearing Interferometry with Deep Learning-Assisted Shear Estimation
	Lunch
	Afternoon lecture session – chaired by Petr Bouchal
14:00-14:20	Kateřina Sedláčková (Altium): Small Footprint, Big Insight: Holomonitor for Incubator Cell Monitoring

14:20-14:50	Veronika Žáková: Quantitative Phase Microscopy: A Versatile Label-Free Platform for Microbiology and Cell Biology
14:50-15:20	Michaela Shiotani Marcondes: Precision phototherapy: advantages of holographic incoherent-light-source quantitative phase imaging in cancer treatment
15:20-15:50	Alan Boyde: Possible dry measurement of dry cell mass using cathodoluminescence of glass substrate in an SEM
15:50	Group photo
16:00-18:00	Poster session
18:10	*Conference dinner – Jean Paul's Restaurant, Purkyňova 107, Brno*

Thursday 15th October

	Morning lecture session – chaired by Jakub Bělín
9:00-10:00 KEYNOTE	Adrian Podoleanu: Real Time Acquisition and Display of En-face Optical Coherence Tomography
10:00-10:30	Zdeněk Hradil: What Every Optical Physicist Should Know About Quantum Phase: A Century of Confusion and Progress
	Coffee break
11:00-11:30	Ivana Michálková: Holographic Incoherent-light-source Optical Diffraction Tomography: A Comparison of Reconstruction Strategies
11:30-12:00	Petr Bouchal: On the quantitativeness of quantitative phase imaging
12:00-12:30	David Mills: Do we need Phase in µCT?
	Conference closing and lunch

Poster session

Jakub Cibulka: Correlating material properties and function of biomolecular condensates in DAN repair
Ewan Drever-Smith: Compact multimodal illuminator for versatile quantitative phase microscopy
Tomáš Groušl: Comparison of holotomographic microscopy and coherence-controlled holographic microscopy
Jan Sebastian Hemzal*:* Three-Dimensional Physics-Informed Deep Neural Network for Scalar Scattered Fields Prediction
Nicole Horáková: Calcium Oxalate crystal isolation and formation in the family *Araceae*
Eliška Michalicová: Semi-analytical algorithm for refractive index reconstruction of an object obscured by the scattering layer
Matěj Špaček: hiQPI microscope setup for optical diffraction tomography
Aneta Křížová: The Use of Software-Based Autofocus for Quantitative Phase Imaging of Cells in a 3D Environment
Ondřej Červinka: Establishing a Library of Metasurface Building Blocks through Coherence-Controlled Holographic Microscopy

KEYNOTE LECTURE

From Quantitative Phase Imaging to Neuropsychiatric Disorders: Twenty Years of Digital Holographic Microscopy

Prof. Pierre Marquet, Ing. Phys. (EPFL), MD, PhD, FMH

Centre for Psychiatric Neuroscience (CNP), Lausanne University Hospital (CHUV), Switzerland; CERVO Brain Research Centre, Université Laval, Québec, Canada.

Abstract

Over the past two decades, digital holographic microscopy (DHM) has evolved from a label-free optical imaging technique into a quantitative tool for probing cellular structure and dynamics. This lecture will present key instrumental advances, including polychromatic DHM, enabling high-precision phase measurements, together with strategies to translate quantitative phase signals into biophysical cellular parameters and processes. Combined with iPSC-derived human neurons and artificial intelligence, this approach enables the identification of disease-specific functional signatures of neuropsychiatric disorders. It reveals promising biomarkers for bipolar disorder and schizophrenia, with potential impact on diagnosis, treatment, and mechanistic understanding.

LECTURE

Nanorobot-Cell Communication via In Situ Generation of Biochemical Signals

Xiaohui Ju[1,2], Roshan Velluvakandy[2], Martin Pumera[1,2]

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Abstract

Achieving precise control of cellular processes drives possibilities for next-generation therapeutic approaches. However, existing technologies for influencing cell behavior primarily rely on specific drug delivery, limiting their ability to mimic natural cellular communication processes. In this work, we developed glucose-powered gold-silica (Au-SiO2) nanorobots that induce cell migration by generating steady-state hydrogen peroxide (H2O2) as a biochemical signaling molecule to mimic natural cellular communication with high spatial resolution. These nanorobots leverage the unique 2-in-1 catalytic activity of gold nanoparticles for glucose oxidation and H2O2 decomposition, allowing for precise control over the generation of steady-state H2O2 concentration and enhanced diffusion powered by glucose within the cellular microenvironment. We further demonstrated that at low dosages of nanorobots, the steady-state H2O2 generation promotes cell migration and proliferation, while higher dosages of nanorobots slow down cell proliferation. The proposed design of this biocompatible nanorobot is intended to enable communication with the environment and provide a noninvasive, biochemical command system for regulating cellular behavior. Additionally, we show proof of principle of a method by which nanorobots can augment wound healing and similar regenerative therapies [1].

References

[1] ACS Nano 2025, 19, 25, 22953–22967

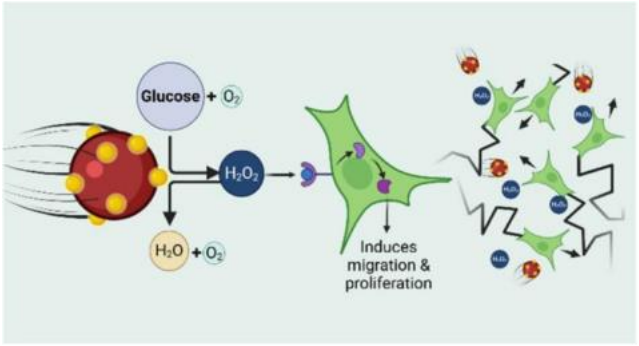


Figure 1. Schematic representation of using Au-SiO2 nanorobots to communicate with cells.

KEYNOTE LECTURE

Metrological characterization and validation of QPI systems in life sciences

Prof. Malgorzata Kujawinska

Institute of Micromechanics and Photonics, Warsaw University of Technology, Poland.

Abstract

2D and 3D Quantitative Phase Imaging (QPI) is particularly useful as advanced imaging and measurement tool in biomedical research, but its performance is sample-dependent and cannot be reliably characterized with conventional approach to metrology. In order to characterize and benchmark wide range of QPI systems, it is crucial to use phantoms that represent key details of the sample in realistic working conditions, and evaluate the systems in an end-to-end fashion. This presentation summarizes the metrological needs and protocols for the QPI systems, as well as presents 3D-printed microphantoms ranging from simple bars, steps, cells and cell cultures, up to volumetric and scattering phantoms mimicking tissues or organoids. Such phantoms are characterized by traceable and calibrated instruments and therefore they seem to be invaluable tool to certify QPI instruments and enable reliable measurement outcomes.

LECTURE

Reliable Uncertainty Quantification for Model-based Interferometric Metrology of Semiconductor Structures

Damian Suski*[a], Julianna Winnik[b], Azeem Ahmad[c], Balpreet S. Ahluwalia[c], Maciej Trusiak[b]

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[b]Warsaw University of Technology, Institute of Micromechanics and Photonics, 8 Sw. A. Boboli St., 02-525 Warsaw, Poland;
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Abstract:

Reliable dimensional metrology is essential for the fabrication and quality control of semiconductor devices [1,2]. Recently, we introduced a novel model-based Bayesian framework for geometrical characterization of nanostructures basing on a single interferogram [3]. The method estimates posterior probability distributions of model parameters (such as object height and width) by evaluating the discrepancy between measured and modelled interference patterns. Bayesian inference provides direct uncertainty quantification, a key component of a measurement result, but its computational cost limits practical applications. To provide computationally efficient parameter estimation, we developed an optimization-based framework [4]. The uncertainties for optimal parameter estimates are evaluated using the standard variance approximation for nonlinear least-squares problems. However, this approach relies on numerical differentiation of the model discrepancy vector, which introduces computational errors and leads to noticeable differences compared to accurate Bayesian uncertainty estimates.

In this work, we propose a novel uncertainty estimation method. We fit a quadratic model to objective function values evaluated at randomly sampled parameter vectors in the vicinity of the optimum. The resulting Hessian is used to estimate the parameter variance vector, while introducing only negligible computational overhead. The proposed method was validated for the geometrical characterization of an optical waveguide (Fig. 1) with rib heigh of only 8 nm and made of silicon nitride material. The obtained confidence intervals show very good agreement with Bayesian posterior distributions.

References:

[1] Wang, J. et al., *Laser & Photonics Reviews*, Vol. 19(3), 2400942 (2026).
[2] Labonté, L et al., *PRX Quantum*, Vol. 5, 010101 (2024).
[3] Suski, D. et al., *Laser & Photonics Reviews*, Vol. 20(12), e03158 (2026).
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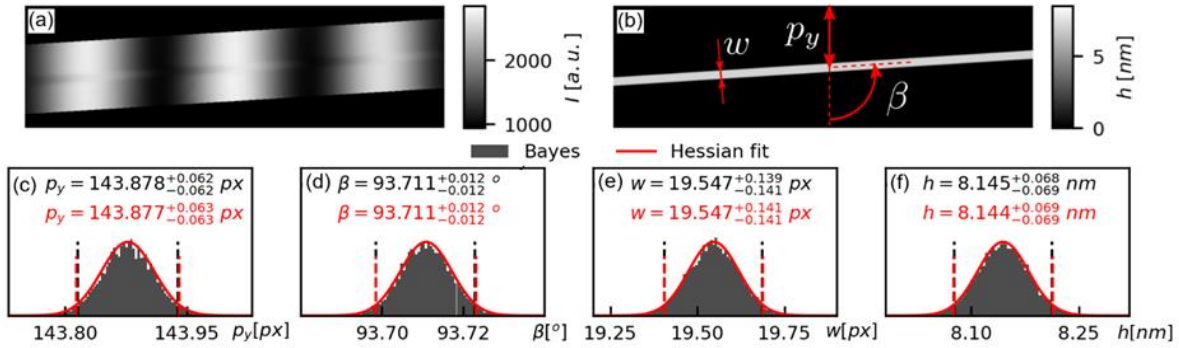


Fig. 1.

Waveguide measurement results. Measured interferogram (a). Object's height map for optimal estimates of waveguide geometrical parameters (position - p_y, orientation - β, width - w, height - h). Comparison of uncertainties calculated with Bayesian inference (gray) and Hessian fit (red) algorithms (c-f). Solid lines – probability distributions, dashed lines – confidence intervals.

Funding: National Science Center Poland, PRELUDIUM BIS grant no. 2022/47/O/ST7/02360

LECTURE

Holographic Incoherent-light-source Optical Diffraction Tomography: Optical Sections of Refractive-Index Structure

Radim Chmelik[1,2], Zbynek Dostal, Monika Kocourkova, Vera Kollarova, Ivana Michalkova, Michala Slaba, Matej Spacek

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Abstract:

Optical diffraction tomography (ODT) provides label-free 3D refractive-index (RI) maps and is attractive for biological applications, including analysis of living patient biopsies. We present Holographic Incoherent-light-source Optical Diffraction Tomography (hiODT), which replaces angularly scanned coherent projections by an axial stack of optical sections acquired by Holographic Incoherent-light-source Quantitative Phase Imaging (hiQPI) [1,2].

hiQPI uses spatially incoherent illumination in an off-axis holographic microscope. Its limited coherence volume provides coherence gating: only corresponding object and reference fields interfere, forming parallel confocal-like channels without point scanning. The recovered complex amplitude therefore represents a depth-resolved optical section of an unlabeled specimen, analogous to confocal sectioning but with quantitative phase contrast. This is illustrated experimentally on a biological sample.

For weakly scattering objects in the first Born approximation, the hiODT volume is formed by arranging hiQPI sections at their acquisition depths. Its Fourier spectrum is identical to that of angle-scanning coherent ODT integrated over illumination directions. The hiODT signal is the 3D convolution of the sample scattering potential with the system amplitude point-spread function. Since the scattering potential is approximately proportional to the deviation of the refractive index (RI) from its background value, each voxel represents spatially filtered local RI contrast. Simulated and experimental hiODT reconstructions show close agreement with conventional ODT.

Finally, coherence-gate manipulation enables hiQPI to detect non-ballistic, multiply-scattered light [3]. Incorporating this complementary information into hiODT may improve fidelity and resolution in strongly scattering samples, opening a route to 3D RI reconstruction of optically thick tissues beyond conventional ODT.

References:

[1] T. Slabý et al., *Opt. Express* **21**, 14747–14762 (2013).
[2] R. Chmelík et al., *Prog. Opt.* **59**, 267–335 (2014).
[3] M. Ďuriš and R. Chmelík, *Opt. Lett.* **46**, 4486 (2021).

LECTURE

The scaling of cellular growth

Václav Bočan[1], Tommaso Cossetto[2,3], Pablo Sartori[2], Jonathan Rodenfels[1]

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Abstract

Proliferating cells require a continuous supply of nutrients to double their biomass before each division. Nutrients consumed are converted into biomass-building blocks through metabolism, with energy harnessed for biosynthesis and waste products excreted. While the molecular machinery of metabolism is complex, the system as a whole is governed by fundamental yet simple physical laws: the conservation of mass and energy and the second law of thermodynamics. These constraints limit the possible configurations of cellular metabolism. However, how human cells navigate these boundaries to meet their energetic demands remains an open question.

To answer this question, we quantify the scaling relationships of human cell metabolism in vitro using a standardized, multimodal approach. By parallel measurements of heat dissipation (calorimetry), oxygen consumption (respirometry), biomass accumulation (QPI), and metabolite uptake and release (NMR spectroscopy), we capture the full spectrum of mass and energy fluxes. We observe a constant ratio between heat dissipation, oxygen consumption, and biomass growth, indicating a tightly regulated, proportional scaling of metabolic inputs and outputs. The mass-specific metabolic rate of actively growing cells is approximately 180 W/kg, roughly 20 times higher than the basal metabolic rate of the entire human body with little to no cell growth. Extending our analysis further using a previously developed minimal thermodynamic framework [1], we calculate the underlying thermodynamic features of cellular metabolism. We observe elevated entropy production that matches well the fermentative metabolic features: substantial lactate accumulation and elevated heat-to-oxygen ratio.

In summary, our work establishes a comprehensive methodological framework that integrates QPI with other techniques to provide a complete quantitative picture of cellular energetics. Our approach can be used to understand how changes in cellular physiology (e.g., in development or cancer) are reflected in the metabolic profiles of cells.

References

[1] Cossetto, T., Rodenfels, J. & Sartori, P. Thermodynamic dissipation constrains metabolic versatility of unicellular growth. Nat Commun 16, 8543 (2025).

KEYNOTE LECTURE

Digital Holographic Microscopy for Cytometry and Histology

Dr. Björn Kemper

Biomedical Technology Center of the Medical Faculty, University of Muenster, Germany

Abstract

In an overview, concepts and systems for digital holographic microscopy (DHM)-based quantitative phase imaging (QPI) with focus on automated multimodal imaging for enhanced throughput are presented. The capabilities of QPI with DHM are illustrated by selected biomedical applications. These include utilization of DHM as tool for determining cell motility and growth dynamics during in vitro drug and toxicity testing based on physical and morphology related parameters down to the single cell level. In addition, the potential in histology is demonstrated by the quantification of inflammation and nanomaterial-induced pathological alterations in ex vivo colon and lung tissue sections. Results from holographic image flow cytometry and perioperative monitoring of living primary human blood cells after cardiac surgery prospect DHM as a cytometric tool for temporal disease course characterization.

LECTURE

Enrichment of higher charge density subspecies of random polyelectrolyte copolymer in complex coacervate

Ioannis Sampson[1,2], Patrick M. McCall[3], **Emmanouela Filippidi**[1,2,4]

[1] Dept. Materials Science and Engineering, University of Crete, Heraklion, Crete, Greece
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Abstract

Quantitative phase microscopy can be an excellent tool aiding in the construction of quantitative phase diagrams of liquid-liquid phase separating species without relying on fluorescent tagging methods.

Mixing pH-adjusted solutions of oppositely-charged polyelectrolytes results in the formation of polyelectrolyte complexes. We explore the spontaneous liquid-liquid phase

separation which results in a polymer-rich phase coexisting with a polymer-poor phase, known as complex coacervation, in the context of the complexation of a strong polyelectrolyte charged at every monomer poly(diallyldimethylammonium chloride) and the weak, randomly modified, carboxy-methyl dextran. Our studies focus in the effect of added monovalent salt. With the use of quantitative phase microscopy, we quantify the difference between the refractive index of the dense and the dilute phases and convert that to concentration differences. Solution NMR provides the partitioning of each of the monomers (positively charged, negatively charged and neutral) in the dilute phase or under non-phase- separating conditions, while inductively coupled plasma mass spectrometry establishes the salt partition between phases. Ultimately, we construct highly precise phase diagrams.

Our results exhibit the enrichment of the dense phase by the weak polyelectrolyte's higher charge density subspecies. Whereas in synthetic polyelectrolytes the partitioning relies on both polymer length and linear charge density, the extension of our observation for monodisperse proteins may explain how post-translational modifications that alter a protein's charge density could directly control the partitioning inside versus outside condensates.

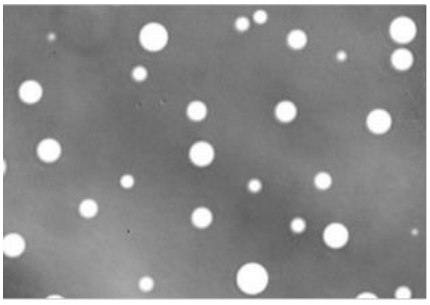


Figure 1. Phase image of coacervate droplets under 15 mM added NaCl.

KEYNOTE LECTURE

Computational lensless holographic imaging from deep-UV to near-IR on a standard sensor

Prof. Maciej Trusiak

Institute of Micromechanics and Photonics, Faculty of Mechatronics, Warsaw University of Technology, Poland.

Abstract

Lensless holographic microscopy offers a powerful route to high-content two- and three-dimensional imaging over large fields of view, but its broader use is often constrained by limited chemical specificity and by multiple scattering in optically dense samples. In this lecture, I will present a unified lensless imaging framework implemented on a standard CMOS camera and operating across an exceptionally wide spectral range, from deep ultraviolet (~240 nm) to the silicon cut-off near 1100 nm. This platform enables UV absorption imaging with intrinsic chemical contrast, near-infrared complex-field imaging with reduced scattering in turbid specimens, and multiple-scattering-aware phase tomography at gigavoxel scale. Together, these advances show how a simple detector platform can support computational microscopy and tomography across complementary spectral regimes, opening new possibilities for high-throughput and information-rich imaging of complex samples.

LECTURE

Polarization Diffraction Grating-Based Shearing Interferometry with Deep Learning-Assisted Shear Estimation

Julianna Winnik, Michał Kołodziejczyk, Aleksandra Piekarska, Maciej Trusiak, Piotr Zdańkowski

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Abstract

Quantitative phase imaging is widely used in biomedical imaging and optical metrology. Here, we present a common-path shearing interferometer based on two polarization diffraction gratings [1] (Fig. 1(a)) that combines partially coherent illumination with adjustable shear, offering multiple high- signal-to-noise measurement modalities. In the total-shear mode [1], a large shear overlaps the object region of one beam with an object-free region of the other, enabling conventional interferometric phase coding. Alternatively, a small shear enables phase-derivative imaging, which can be followed by numerical integration [2] to recover the object phase distribution. Both modalities, when combined with variable-angle illumination, support tomographic imaging. Conventional refractive index (RI) tomography uses total-shear measurements [1] or integrated small-shear data, whereas gradient RI tomography [3] directly exploits phase derivatives, simplifying reconstruction pipeline and improving visualization of subtle RI variations.

Notably, the small-shear measurement modalities, i.e., phase integration and gradient tomography, require accurate estimation of the shear value, which is generally difficult to achieve. Conventional approaches, such as manual inspection, are labour-intensive, whereas autocorrelation-based method [4] is unreliable for very small shear values. To overcome this limitation, we propose a deep learning-based method for automatic shear estimation. Trained entirely on synthetic data, the proposed method is validated using both simulation and experimental measurements (Fig. 1(b)), demonstrating reliable shear estimation and enabling robust operation of the corresponding measurement modalities.

References:

[1] Zdańkowski, P. et al., *Laser & Photonics Reviews*, Vol. 19(15), 2401474 (2025).
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[3] Winnik, J. et al., *Commun Phys,* Vol 8, 510 (2025).
[4] Shanmugam, P. et al., *Light: Advanced Manufacturing* Vol. 3, 16 (2022).

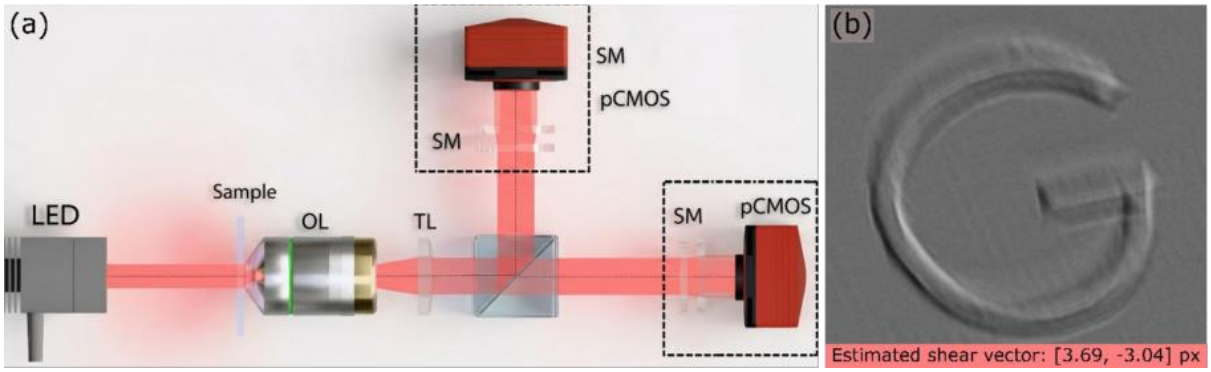


Fig. 1. (a) Common-path interferometer consisting of an LED, objective lens (OL), tube lens (TL), two shearing modules (SMs), each consisting of two polarization diffraction gratings, and a polarization- resolved pCMOS camera. (b) Phase derivative of the test target obtained under tilted illumination (for gradient tomography evaluation), and the shear value estimated by the deep learning model.

Funding: National Science Center Poland, SONATA grant no. 2024/55/D/ST7/02792

LECTURE

Small Footprint, Big Insight: Holomonitor for Incubator Cell Monitoring

Kateřina Sedláčková

Altium International s.r.o.

Abstract

In recent years, digital holographic microscopy (DHM) has gained widespread popularity as a convenient and reliable tool for observing cell populations. Its user-friendly, fully automated workflow enables long-term, label-free imaging without the need for chemical stains or fluorescent labels, which can introduce unwanted cytotoxic effects and interfere with normal cellular behavior. By combining quantitative phase imaging with non-invasive data acquisition, DHM provides high-quality images while preserving the natural characteristics and dynamics of living cells.

HoloMonitor is a compact digital holographic microscope that enables quantitative, label-free imaging of live cells. Its non-invasive technology allows long-term monitoring of cell morphology, motility, interactions, and population dynamics without compromising cell integrity. Its compact design allows the system to be placed directly inside a standard incubator, making it well suited for extended live-cell experiments.

The presentation will introduce the HoloMonitor platform and its analytical modules for quantitative cell characterization.

LECTURE

Quantitative Phase Microscopy: A Versatile Label-Free Platform for Microbiology and Cell Biology

Veronika Žáková[1,2], Sverre Branders[3], Vimarsh Awasthi[2], Manfred Grabherr[3], Rafi Ahmad[3], Yakubu P. Abudu[4], Balpreet S. Ahluwalia[2]

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[2] Nanoscopy Group, Department of Physics and Technology, UiT – The Arctic University of Norway, Tromsø, Norway

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Abstract

Quantitative phase microscopy (QPM) is a label-free optical technique that reconstructs the specimen-induced phase shift, enabling non-invasive extraction of biophysical parameters such as dry mass, volume and sphericity [1]. Interferometric QPM has recently enabled label-free tracking of bacterial dry mass under antibiotics [2,3] and of cell biophysics [4]. Four applications of this versatile platform are summarised below, developed jointly by CEITEC (Brno University of Technology) and the Nanoscopy Group, UiT – The Arctic University of Norway.

QPM-based dry-mass monitoring over 24 h of antibiotic exposure distinguished resistant from susceptible E. coli and S. aureus strains, demonstrating a rapid, label-free approach to antimicrobial susceptibility testing (AST).

Combining QPM with Raman spectroscopy and machine learning enabled multimodal classification of six bacterial species (three Gram-positive, three Gram-negative), achieving>99% accuracy at the species level and >96% accuracy for the resistance profile, demonstrating that biochemical and biomorphological readouts are complementary for AMR diagnostics.

The same configuration was used to monitor Deferiprone-induced mitophagy in HeLa cells label-free, revealing a biphasic trajectory in dry mass and sphericity that would otherwise be obscured by fluorescent labelling, highlighting the benefit of label-free readouts for mitochondrial quality control studies.

Ongoing work extends this profiling to the methanotrophic bacterium Methylocapsa Gorgona, testing whether dry mass and shape descriptors resolve phenotypic differences between cells grown at different temperatures.

To extend QPM to live-cell studies, a 3D-printed microfluidic flow chamber with an integrated perfusion system is being developed to ensure full compatibility with the microscope, enabling controlled, real-time imaging under defined environmental conditions.

Together, these four applications illustrate QPM's versatility as a label-free platform that bridges microbiology, cell biology, and instrument development, with strong potential for future integration with machine learning and microfluidics towards real-time, quantitative diagnostics.

References

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LECTURE

Precision phototherapy: advantages of holographic incoherent-light-source quantitative phase imaging in cancer treatment

Michaela Shiotani Marcondes[1], Daniel Zicha[1,2]
[1]CEITEC - Central European Institute of Technology, Brno University of Technology, Purkyňova 656/123, 612 00 Brno, Czech Republic
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Abstract

Cancer cell migration is a major driver of metastatic progression and therapeutic resistance, highlighting the need for quantitative, label-free approaches to detect dynamic phenotypic changes at the single-cell level. Holographic Incoherent-light-source Quantitative Phase Imaging (hiQPI) enables non-invasive assessment of cellular morphology, dry mass distribution, and motility without fluorescent labeling. Previous studies show that dynamic parameters derived from quantitative phase imaging, including migration speed, protrusion polarity, and information flow polarity, provide descriptors of migratory behavior and treatment-induced phenotypic modulation [1-4].

In this work, hiQPI was applied to metastatic melanoma A375M2 cells treated with potential migrastatic compounds - drugs targeting cancer cell invasion and metastasis, rather than cell proliferation [5] - targeting distinct pathways, including Netarsudil (NET), Niclosamide (NIC), and GDC0941 (GDC). Cells were cultured in Dulbecco's modified Eagle's medium supplemented with 10% fetal bovine serum and maintained at 37 °C in a humidified atmosphere containing 5% CO_2. Time-lapse phase images were acquired every 5 min over 10 h at multiple positions per condition, providing sufficient temporal resolution to characterize migratory behavior at the cellular level. Phase images were processed using custom routines implemented in Mathematica, and single-cell trajectories were extracted for quantitative analysis. Migration speed, protrusion polarity, inflow-outflow polarity, and circularity were used as complementary descriptors of cell behavior, capturing motility, protrusion-retraction, cell morphology and a novel, promising biomarker, dynamic polarity.

By combining the parameters mentioned earlier this approach provides a multidimensional framework for evaluating cancer cell responses to potential migrastatic compounds. The study aims to assess whether hiQPI-derived parameters can serve as complementary, cell-type-sensitive biomarkers for characterizing drug-induced phenotypic modulation beyond migration measurements.

References

[1] Šuráňová, M. et al., Biomedical Optics Express, Vol. 14, 2689 (2023).
[2] Zicha, D. and Chmelik, R., Methods in Enzymology, Vol. 679, 255–274 (2023).
[3] Zicha, D., Scientific Reports, Vol. 12, 1621 (2022).
[4] Dostál, Z. et al., Computer Methods and Programs in Biomedicine, Vol. 268, 108829 (2024)
[5] Rosel, D. et al., Trends in Cancer, Vol. 5, 755-756 (2019).

LECTURE

Possible dry measurement of dry cell mass using cathodoluminescence of glass substrate in an SEM

Alan Boyde, Pavel Vesely, Daniel Zicha

Abstract

Boyde and Reid (1983] described a novel method for imaging biological samples in the SEM using the cathodoluminescence of a subjacent and supporting glass slide or cover slip. One type of sample which we studied at that time were rat fibrosarcoma derived K2 cells (Vesely et al 1994; Pokorná et al 2003).

Cells were grown on glass cover slips, fixed with formaldehyde and freeze-dried or critical point dried, then given a conductive coating of aluminium by evaporation. Glass is strongly and uniformly cathodoluminescent. The CL signal is collected by an aluminium foil or a PMMA light guide placed under the glass and directed to a photomultiplier such as is standard in Everhart-Thornley secondary electron detector systems in SEMs.

The dry cell mass scatters or absorbs the incoming electron beam, reducing the strength of the CL signal.

The SEM used at that time was a Cambridge Instrument Co. Stereoscan mark 1 instrument operated at 20kV accelerating voltage and 10pA beam current. Images were recorded by photographing the SEM CRT display monitor on 35mm film. Here, we digitised the original Ilford FP4 film negatives using an Epson film scanner and processed the resultant digital images.

To make images which strongly resemble light microscopic quantitative phase images of live cells (Dunn and Zicha 1994), we inverted the CL image, normalised the histogram and used the Hall LUT, as shown in the accompanying figure.

This procedure could be emulated in any modern digital SEM, provided a similar detector geometry could be retrofitted, and used to study really-dry dry cell mass, and correlated with live quantitative phase imaging.

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KEYNOTE LECTURE

Real Time Acquisition and Display of En-face Optical Coherence Tomography

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Abstract

Optical Coherence Tomography (OCT) has been initially developed as a non invasive high resolution optical imaging modality for ophthalmology, followed by rolling the technology to other medical fields as well as to non destructive testing. I will present the bottleneck in digital signal processing raised by the combination of an interferometer with a multi MHz tuning rate laser as well as solutions to display en-face OCT slices in real time. We proposed an alternative OCT method that does not rely on a Fourier Transform and changes the main result of signal processing, from information along the axial coordinate to that along the transversal coordinate. This method, of Leader Follower (LF) [1] and its several facets, Complex Leader Follower (CLF) [2] and Downconversion Leader Follower (DLF) [3] will be presented. DLF can serve delivery of en-face OCT images in principle at any high sweeping rates, of MHz or tens of MHz.

I will also show how Master students from Brno University of Technology have contributed to the progress of OCT through numerous regular exchange stages in Kent over the last 15 years.

LECTURE

What Every Optical Physicist Should Know About Quantum Phase: A Century of Confusion and Progress

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Abstract

Quantum phase has played a central role in optics since the early days of wave theory. While phase is a perfectly well-defined concept in classical optics, its quantum-mechanical description has remained surprisingly subtle. Starting from Dirac's pioneering attempt to introduce a phase operator in 1927 [1], this lecture reviews the historical development of quantum phase, the long- standing difficulties associated with defining a quantum phase observable, and the modern understanding of phase estimation as a statistical inference problem.

The historical discussion naturally leads to the modern framework of statistical estimation based on Fisher information and quantum Fisher information, highlighting both their power and their limitations as measures of metrological performance. Particular attention will be paid to the role of phase periodicity, prior information, resource accounting, and estimator construction. These considerations offer a different perspective on widely discussed concepts such as Heisenberg scaling, NOON-state interferometry, and the claimed advantages of quantum sensing.

The lecture argues that many apparent paradoxes disappear once quantum phase is treated consistently as an estimation problem rather than as an observable. Throughout the presentation, classical optics serves as a valuable guide for interpreting quantum measurement protocols and for distinguishing genuine physical limits from artefacts of mathematical idealization.

A central message of the lecture is that quantum metrology should not be viewed as a discipline separate from classical metrology. Rather, it extends the operational and statistical framework of classical estimation theory to quantum measurements. This unified perspective helps identify genuine quantum advantages while avoiding misleading conclusions based solely on idealized quantum bounds.

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LECTURE

Holographic Incoherent-light-source Optical Diffraction Tomography: A Comparison of Reconstruction Strategies

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Abstract

Optical Diffraction Tomography (ODT) is a quantitative phase imaging (QPI) technique that enables three-dimensional reconstruction of the refractive index distribution (RID) of a sample without external labeling. This label-free capability makes ODT particularly attractive for biological and biomedical applications, including live-cell imaging [1–3].

Conventional ODT implementations typically employ transmission interferometry with coherent illumination and sequential acquisition under varying illumination angles. While effective, these systems are susceptible to coherence-induced artifacts and often require complex beam-steering or illumination-control mechanisms. Alternative approaches based on temporally or spatially incoherent illumination can mitigate some of these limitations [4–10].

Recently, Holographic Incoherent-light-source QPI (hiQPI) [11], combined with axial scanning, has enabled a new ODT modality termed Holographic Incoherent-light-source ODT (hiODT) [12]. By exploiting the coherence-gating properties of incoherent illumination, hiODT provides reduced coherence noise and inherent optical sectioning. However, as in other limited-angle tomographic approaches, reconstruction remains challenged by the missing cone and requires algorithms that can effectively recover the unmeasured spatial frequencies [13].

Here, we investigate four reconstruction strategies for hiODT: a physics-based iterative optimization method, a neural-network (NN)-based approach, and two hybrid methods that combine the rapid inference of neural networks with the physical consistency and robustness of iterative reconstruction. We systematically compare their performance, highlighting the trade-offs between reconstruction accuracy, robustness, and computational efficiency.

Finally, we discuss current limitations and future directions toward improving the reconstruction quality and practical applicability of hiODT.

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LECTURE

On the quantitativeness of quantitative phase imaging

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Abstract

Quantitative phase imaging (QPI) is an established technique with applications in biological imaging and metrology. QPI is commonly based on interference between a probe field and a well-defined reference field and can be implemented using various holographic architectures, each offering different compromises between image noise, environmental stability, and temporal resolution [1].

Despite the quantitative nature of holographic imaging, theoretical models often rely on simplifying assumptions and do not fully account for real-world effects that influence the measured data. Here, we investigate the effects of temporal [2] and spatial coherence of the illumination and light diffraction on quantitative phase measurements [3]. Theoretical models are supported by experimental evidence, providing a more accurate basis for data reconstruction and interpretation and helping to avoid systematic misinterpretation of the measured data. The results further demonstrate the potential of super-resolved QPI to improve spatial resolution while also increasing measurement accuracy [3].

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LECTURE

Do we need Phase in µCT?

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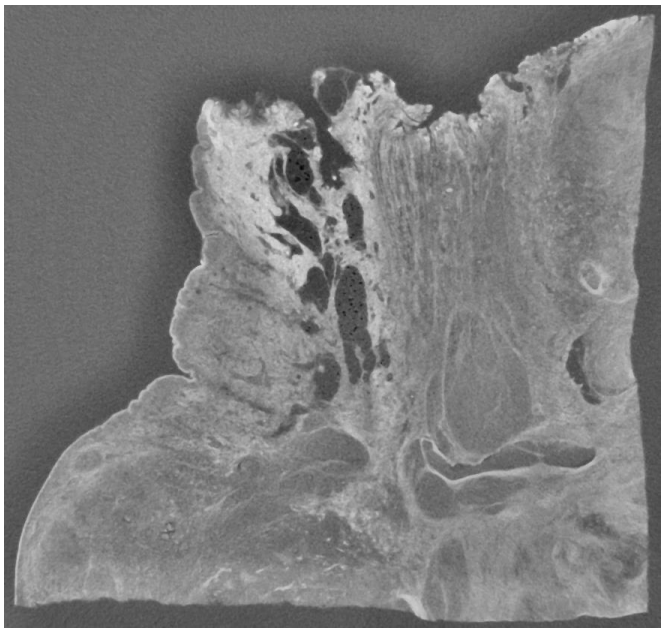
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I've recently been asked to image some thyroid cancer samples embedded in wax prior to sectioning for histology, to guide sectioning to interesting areas. Ultimately, the surgeons would like us to image at least 100 samples.

The surgeons assumed we had phase-µCT in the lab and asked us to use it; they wanted to replicate results reported in the literature. My phase-µCT system is slow, very slow and difficult to configure; one block would take around 48 h to scan.

Several other groups in London have in-house constructed phase-µCT, but none are up to the challenge of 100 samples.

I've optimised our high-contrast resolution µCT to image the wax blocks at 20µm spatial resolution and to use post-processing in Fiji/ImageJ to further increase contrast. We can image three blocks simultaneously, reducing scan times to 12-18 h. This allows all 100 blocks to be imaged in about a month if we tie up one scanner for the project, or three months on a more realistic time scale.



Poster

Comparison of holotomographic microscopy and coherence-controlled holographic microscopy

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Abstract

Quantitative phase imaging (QPI) is a powerful tool for label-free visualisation of living cells. Here, we compare two QPI microscopes - the Telight Q-Phase microscope and the Nanolive 3D Cell Explorer-fluo microscope. Both systems provide unbiased information on cell morphology, including individual cell dry mass, perimeter, and area. The Q-Phase microscope uses artefact-free, coherence-controlled holographic imaging technology to visualise cells in real time with minimal phototoxicity. The 3D Cell Explorer-fluo employs laser-based holotomography to reconstruct 3D images of living cells, visualising their internal structures and dynamics. Here, we analysed the strengths and limitations of both microscopes when examining two morphologically distinct cell lines: the cuboidal epithelial MDCK cells, which form multicellular clusters, and the solitary-growing Rat2 fibroblasts. We focus mainly on the devices' ability to generate images suitable for single-cell segmentation using the built-in software, and we discuss the segmentation results and quantitative data derived from the segmented images. We show that both microscopes offer distinct advantages, and the choice between them depends on the user's specific requirements and goals [1].

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Poster

Three-Dimensional Physics-Informed Deep Neural Network for Scalar Scattered Fields Prediction

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Abstract

The computational cost of conventional numerical solvers remains a major challenge in Optical Diffraction Tomography (ODT), particularly for the iterative reconstruction of three-dimensional refractive-index distributions. PINNs can provide an alternative approach, in which the governing physics equations are incorporated directly into the training process, enabling rapid field predictions without the need for labelled datasets. PINNs can employ the scalar Helmholtz equation to model wave propagation and predict the scattered fields [1] or use the full-vector Maxwell formulation to predict the electromagnetic fields [2].

In this work, a computationally efficient three-dimensional scalar PINN that directly incorporates the Helmholtz equation into its loss function is implemented. The proposed network is trained to predict scalar scattered fields from spherical samples with varying refractive indices and positions within the computational domain. Its performance is subsequently evaluated on more complex geometries to assess its generalisation capability. The predicted fields are compared with reference solutions obtained from COMSOL simulations, as well as with results from the approximate multi-slice beam propagation

method (BPM) [3] and the multi-layer Born (MLB) multiple-scattering model [4]. On an NVIDIA GeForce RTX 4090, inference times for the trained three-dimensional scalar PINN were approximately 6 ms, 15 ms, and 122 ms for computational domains of 643 1283 and 2563, respectively.

The proposed network is intended to serve as the forward-modelling component of a reconstruction framework for recovering three-dimensional refractive-index distributions from measured hiODT (Holographic Incoherent-light-source Optical Diffraction Tomography) z-stack data. Once trained, the network provides rapid scattered-field predictions, substantially reducing the computational cost of repeated forward simulations.

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Poster

Calcium Oxalate crystal isolation and formation in the family Araceae

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Abstract

Calcium oxalate (CaOx) crystals are widespread biominerals in plants, yet the molecular mechanisms governing their formation, organization, and regulation remain poorly understood. Processes such as crystal nucleation, polymorph selection, spatial arrangement, and the role of crystal-associated proteins require further investigation. Additionally, the influence of environmental and physiological factors on crystal development, including ion availability and abiotic stress, remains largely unexplored.

This study investigates calcium oxalate biomineralization in members of the *Araceae* family, focusing on crystal isolation from *Dieffenbachia* sp. and stress-response experiments in *Lemna minor*. Crystal isolation required methodological optimization due to challenges in obtaining pure crystal fractions and preparing samples for subsequent analyses.

To identify proteins associated with calcium oxalate crystals, proteins extracted from crystal rich fractions were separated using SDS-PAGE. In parallel, *Lemna minor* plants were exposed to different temperatures and varying concentrations of Ca^{2+}, Mg^{2+}, and Na^{+} to assess the effects of ion availability and abiotic stress on crystal formation. Raman spectroscopy was used to identify and characterize calcium oxalate crystals and their polymorphic forms. In future work, Quantitative Phase Imaging (QPI) will be incorporated as a complementary, label-free imaging technique to monitor crystal formation, growth, and spatial distribution in living plant tissues.

Together, these approaches aim to identify proteins involved in crystal development, characterize calcium oxalate crystals, and determine how environmental conditions influence calcium oxalate biomineralization. The planned integration of QPI with established analytical techniques is expected to provide new insights into the dynamics of crystal formation and organization in plants.

Poster

Semi-analytical algorithm for refractive index reconstruction of an object obscured by the scattering layer

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Abstract

Images of living biomedical specimens are usually distorted by light scattering due to the medium in which the sample is placed. If the image distortion is small, one can, for example, filter out the randomly scattered light from the image. The resulting image is then reduced in noise for the cost of suppressing also the resolution [1].

To obtain an image with a preserved resolution and reduced noise at the same time, one can take advantage of both the non-scattered and scattered parts of light [2]. These two entities are described by the transmission function of the medium. This approach, however, requires an accurate scanning module in the measuring device and a huge amount of data needs to be collected and processed.

We present an iterative semi-analytical algorithm for reconstructing the refractive index (RI) of a target object obscured by a strongly scattering layer. As an integral part of the reconstruction process, the transmission function of the scattering layer is simultaneously estimated.

The proposed approach is based on the Gerchberg–Saxton algorithm [1] and enables accurate RI reconstruction while requiring minimal computational resources, since only two measurements are required. The performance and robustness of the method in the presence of noise are demonstrated numerically.

Our results contribute to the development of quantitative phase imaging through turbid media and establish a promising framework for semi-analytical imaging approaches in strongly scattering environments, with potential applications to the reconstruction of three-dimensional RI distributions.

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Poster

hiQPI microscope setup for optical diffraction tomography

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Abstract

Holographic incoherent-light-source Quantitative Phase Imaging (hiQPI) combines the advantages of off-axis holography with low-coherence interferometry, yielding single-shot holograms largely free of speckle noise and coherence artefacts [1]. Owing to these advantages, it has found use in various biological and photonic applications requiring real-time acquisition of high-fidelity phase maps [2,3].

However, the sample thickness and the refractive index are interconnected in a 2D phase map, making the information about these properties ambiguous. Optical diffraction tomography (ODT) addresses this by mapping the 3D distribution of the refractive index and has been successfully used on complex samples such as organoids, tissues, and 3D cell cultures, revealing their inner morphology [4].

Despite its advantages, hiQPI has not yet been adapted for volumetric imaging. Here, we introduce a hiQPI microscope setup capable of tomographic acquisition, present its optical layout and mechanical design, and show a pilot measurement on a glass microsphere sample demonstrating its feasibility.

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Poster

The Use of Software-Based Autofocus for Quantitative Phase Imaging of Cells in a 3D Environment

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Abstract

Quantitative Phase Imaging (QPI) is a powerful label-free technique for quantitatively characterizing biological cells through changes in optical path length. In 3D environments, cell movement along the Z-axis makes maintaining focus during automated time-lapse imaging challenging. Reliable autofocus is therefore essential for accurate QPI throughout the sample volume [1].

In this work, we investigate a software-based autofocus method for QPI of cells embedded in collagen gels. The method automatically identifies the optimal focal plane from image data and adjusts the stage position before each acquisition, enabling continuous tracking of cells along the Z-axis without manual focusing or additional hardware on the Q-Phase microscope [2].

The results demonstrate the potential of software-based autofocus to improve the reliability and automation of QPI in 3D biological imaging. By providing rapid and consistent focusing across different sample depths, the approach enables automated quantitative analysis of cell morphology and dynamics and offers a flexible, cost-effective solution for long-term and high-throughput live-cell imaging.

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Poster

Compact multimodal illuminator for versatile quantitative phase microscopy

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Abstract

COSMIC (Compact Open-Source Multimodal Illumination Cluster) [1], is a novel, condenser free [2] transmitted light illuminator for multimodal microscopy – enabling quantitative phase imaging (QPI) via different phase contrast (DPC), in addition to bright field, dark field and diascopic fluorescence illumination. We demonstrate the versatility of COSMIC across a range of research-grade and open-source microscopes and a variety of specimens, including live-cell co-cultures on a uSIM microfluidic device [3] and living Caenorhabditis elegans. We validate and calibrate quantitative phase measurements and demonstrate a system-independent alignment method that does not require access to the system back focal plane. The low physical complexity of COSMIC yields a low-cost illuminator compatible with compact systems and very short light paths. By open-sourcing both the hardware and software of COSMIC we provide a straightforward route to multimodal and quantitative phase imaging on a wide range of optical microscopy systems, using minimal optomechanics, and demonstrate cross-platform support for both research-grade and resource-constrained microscopy environments.

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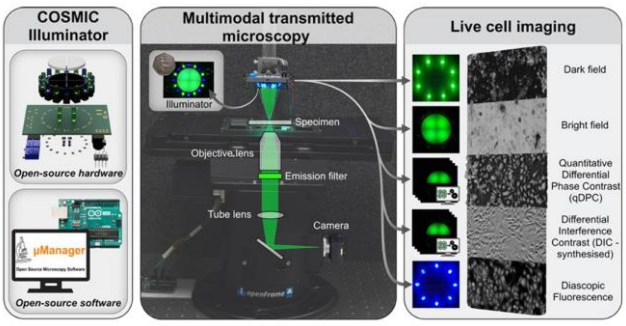


Figure 1 – COSMIC construction, example system arrangement and overview of imaging modalities (specimen is a live cell co-culture)

Poster

Correlating material properties and fuction of biomolecular condensates in DNA repair

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Abstract

Biomolecular condensates form through phase separation of proteins and nucleic acids to reversibly organize cellular processes into defined compartments. Their function often relies on a complex architecture with multiple immiscible phases, each of them permissive for a distinct set of molecules and biochemical reactions. We recently reported that DNA double-strand breaks arising within condensed heterochromatin are protected from aberrant recombination by NUP98 condensates until the breaks relocate to the nuclear periphery for safe repair [1]. *In vitro*, NUP98 forms biphasic condensates with the heterochromatin protein HP1α, and we hypothesize that their mutual immiscibility generates capillary forces that drive NUP98 condensates to the surface of the heterochromatin domain. Here we employed quantitative phase imaging (QPI) combined with atomic force microscopy (AFM) to probe the material properties of both NUP98 and HP1α phases. Our preliminary data show that NUP98 condensates are significantly denser and more rigid than HP1α condensates, correlating with our fluorescence microscopy observations. We aim to extend this approach to relate condensate material properties to their miscibility and permeability for repair factors, revealing how the physical state of a condensate determines which factors reach a break, and when.

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Poster

Establishing a Library of Metasurface Building Blocks through Coherence-Controlled Holographic Microscopy

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Abstract

Optical metasurfaces made of high-index dielectrics such as TiO_2 and Si can exceed 90% scattering efficiency, yet their design usually relies on numerical simulations (FDTD, RCWA). These simulations rarely capture real fabrication imperfections such as edge rounding, size deviations, surface roughness, or variations in material density. Far-field intensity measurements reveal only the overall device response, and scattering-type near-field microscopy is slow and limited to small fields of view. Here we demonstrate coherence-controlled holographic microscopy (CCHM) as a fast, single-snapshot method for building experimental libraries of metasurface building blocks. We modified a commercial CCHM (Telight Q-Phase) with a monochromator and a rotatable linear polarizer, which enables direct amplitude and phase imaging over 600–740 nm. Anisotropic TiO_2 nanostructures were fabricated on fused silica by electron-beam lithography and atomic layer deposition by a modified damascene process. The nanostructures had lateral dimensions of 130-330 nm, a 450 nm period, and a 500 nm height. While RCWA and FDTD simulations predicted full 2π phase coverage, in the measurements, the phase response saturated at 1.25π. As a result, a designed half-wave plate would only work as a quarter-wave plate in practice. Focused ion beam cross-sections traced this discrepancy to internal voids in the high-aspect-ratio. The voids reduce the accumulated phase and shift the resonance positions. CCHM also resolved the polarization-dependent phase response of the structures. Varying the condenser numerical aperture from 0.05 to 0.5 had a negligible effect, which shows the building blocks are robust to illumination conditions. CCHM therefore enables experimental "metalibraries" that include every fabrication and material imperfection, which can then be used for the design of high-performance metasurfaces.

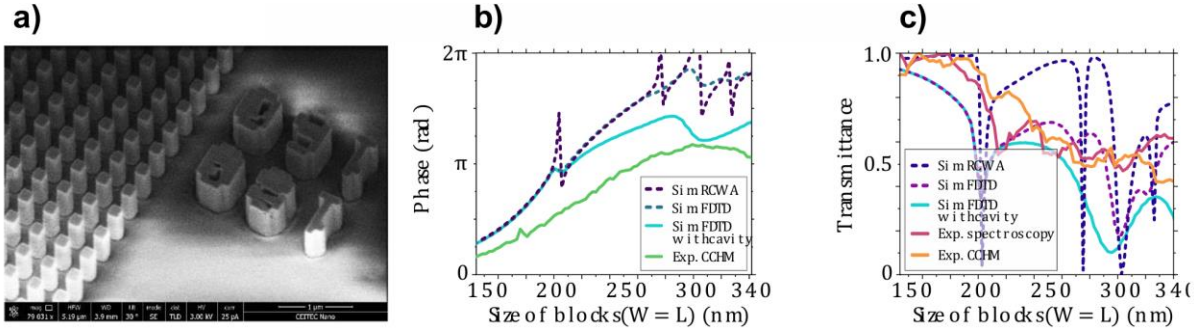


Fig. 1: Fabricated nanostructures and comparison of experimental and simulated a) phase and b) amplitude response.

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