SenDiSo Workshop:

Bridging between Materials Research and Advanced Sensor and Detector Technologies

Date: June 16th 2025
Venue: Sál V. Dvořáka: hlavní sál" - A/1.NP/10, FZÚ, Na Slovance 1999/2, 182 00 Praha 8 (entrance from Pod Vodárenskou Věží 1)
Directions: https://www.fzu.cz/en/about-fzu/main-building-na-slovance-site.
Registration link: https://indico.fzu.cz/e/sendiso-workshop-june2025

Program

9:30 – 10:00	Get together, coffee
10:00 – 10:10	Welcome and introduction (J. Dostalek)
10:10 - 10:30	Jan Kral, High loading nanocomposites of cesium lead halide nanocrystals for radiation (FZU, WP3)
10:30 - 10:50	Marketa Vrabcova, Antifouling polymer brushes for improved analytical performance in biosensing (FZU, WP2)
10:50 - 11:10	Ivana Venkrbcova, MoS2 deposition by HiPIMS (FZU, WP1)
11:10 - 11:30	Kateřina Jiříková, High-fidelity detection of scattering amplitude and phase (UFE, WP5)
11:30 - 11:50	Bengisu Yöney, Pathogen-on-a-Chip: Impedance-Based Detection of Biofilm Formation and Inhibition by *Staphylococcus aureus* and *Staphylococcus epidermidis,* (MUNI, WP5)
12:00 - 13:00	Lunch
13:00 - 13:20	Jan Kejzlar, Black metals films for chemical sensors (FZU, WP4)
13:20 - 13:40	Vendula Hrnčířová, Metal-diamond complexes with enhanced plasmonic effects (CVUT, WP1)
13:40 – 14.00	Veronika Hovanova, Design and Fabrication of DNA Origami Cubes as Model Systems for Nanofluidic Scattering Microscopy (FZU, WP2)
14:00 – 14.20	Stanislav Michal, Summary of the most important results of the JLO Applied Optics Group (UPOL, WP3)
14:20 – 14.30	Wrapping up (J. Dostalek)
14:30 – 15: 30	Informal discussions, coffee

Zoom link for online participation:

https://bokuvienna.zoom.us/j/65381735221?pwd=5WeacuuqO7taMywoy9h5RpbrjJ2a4g.1

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Abstracts:

High loading nanocomposites of cesium lead halide nanocrystals for radiation detection

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This work focuses on exploiting the excellent luminescent properties of cesium lead halide nanocrystals in radiation detection. Recently, their potential for fast timing applications and chromatic calorimetry has been shown [1,2,3]. To ensure material stability, these nanocrystals are often embedded into a polymer matrix, forming nanocomposite scintillator. For this nanocomposite to be effective in detection of high-energy radiation, achieving high loadings of nanocrystals in the matrix, while maintaining transparency of the material, is crucial and proved challenging when attempted [4]. In our work, we present novel surface modification of the nanocrystals by allyltrimethoxysilane and ammonium hexaflourosilicate. Employment of copolymerizable ligands leads to enhancement of nanocrystal dispersion within the matrix, thereby improving the final material transparency. Meanwhile, improved surface passivation enables us to perform thermally initiated free radical polymerization at temperatures up to 110°C with minimal damage to nanocrystals. This allows us to produce high loading samples with nanocrystal content up 40% by weight or large volume samples [5]. Our findings reveal a significant improvement in time resolution under X-rays compared to previously published values for cesium lead bromide polymer nanocomposites [2]. When combined with increased stopping power of high nanocrystal content, this advancement holds great promise for practical applications in time-of-flight positron emission tomography and high energy physics.

References:

[1] K. Děcká et al., Journal of Materials Chemistry C, 10(35):12836–12843, 2022.
[2] F. Pagano et al., Adv. Mater. Interfaces 2024, 11, 2300659.
[3] A. Devanshi et al., EPJ Web Conf. 320 00029, 2025.
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[5] J. Král et al., *Phys. Mater.* **8** 015007, 2025.

Antifouling polymer brushes for improved analytical performance in biosensing

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Antifouling polymer brushes (PBs) serve as versatile platforms for highly sensitive, label-free biosensing in complex biological media. In this presentation, I will highlight recent advances in the synthesis and application of zwitterionic and nonionic PBs, with a particular focus on poly(carboxybetaine)-based brushes. These coatings, synthesized via surface-initiated atom transfer radical polymerization (SI-ATRP), exhibit excellent antifouling properties, long-term stability, and functionalization potential. Results from a storage stability study confirm that these brushes maintain their antifouling performance and biorecognition capacity over time, supporting their reliability for biosensing applications in industry and research (*1, 2*).
To overcome the limitations of conventional SI-ATRP methods – especially low monomer efficiency – we developed innovative microfluidic reactors. This cost-effective approach significantly improves monomer usage and allows user-friendly synthesis of PB-functionalized substrates at a scale suitable for mass production (~100 substrates/day). I will introduce a microfluidic stack reactor (μSR), 3D-printed using stereolithography techniques. Characterization using infrared (IR) and X-ray photoelectron spectroscopy (XPS), ellipsometry,

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surface plasmon resonance (SPR), and contact angle measurements shows that PBs synthesized in the μSR are comparable in quality to those prepared by traditional SI-ATRP methods (*3*). Furthermore, we extended this concept to metallic reactors, with preliminary results demonstrating that copper μSRs can be used for metal-mediated SI-ATRP to synthesize similar PB coatings.
Finally, I will present results on the synthesis of PBs directly on optical fiber sensors using custom-designed microfluidic capillary reactors. XPS analysis confirmed similar PB thickness and homogeneity on both planar glass and fiber substrates. In model immunoassays, the integration of antifouling PBs with optical fiber sensors led to enhanced sensitivity and specificity required for clinical diagnostics (*4*).

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2. M. Vrabcová, M. Houska, M. Spasovová, M. Forinová, A. Pilipenco, I. Matoušová Víšová, K. Mrkvová, H. Vaisocherová-Lísalová, *Effects of storage on stability and performance of carboxybetaine-based polymer brushes* (SPIE Photonics Europe, SPIE, 2024), vol. 12999.
3. M. Vrabcová, M. Spasovová, V. Cirik, J. Anthi, A. Pilipenco, M. Houska, O. Romanyuk, H. Vaisocherová-Lísalová, N. Scott Lynn, Microfluidic stack reactors for the mass synthesis of polymer brushes. *Chem. Eng. J.* **508**, 160914 (2025).
4. M. Vrabcová, M. Spasovová, M. Forinová, A. Giannetti, M. Houska, N. S. Lynn, F. Baldini, J. Kopeček, F. Chiavaioli, H. Vaisocherová-Lísalová, Optical fibre long-period grating sensors modified with antifouling bio-functional nano-brushes. *Biomater. Sci.* **13**, 1199-1208 (2025).

Deposition of molybdenum disulfide thin films by hybrid HiPIMS/RF reactive sputtering

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Thin films of molybdenum disulfide (MoS_2) were deposited using a hybrid plasma system combining high-power impulse magnetron sputtering (HiPIMS) and radio-frequency (RF) magnetron sputtering from two Mo targets in an Ar + H_2S atmosphere. The HiPIMS pulsed power enabled a high degree of ionization of sputtered metallic particles [1], while the RF power applied to the second target was responsible for gas ionization between HiPIMS pulses [2], thereby increasing the reactivity of H_2S plasma. The molybdenum-to-sulfur ratio in the layers was controlled by adjusting the H_2S flow rate. The MoS_2 films were grown on silicon and quartz substrates and subsequently annealed in pure H_2S RF plasma at a temperature reaching up to 600 °C. The crystalline structure of the films was confirmed by X-ray diffraction (XRD) and Raman spectroscopy. Electronic properties were investigated using the Van der Pauw four-point probe method [3]. Plasma diagnostics was performed by means of an RF plasma probe placed near the substrate [4], under the same conditions as those used during film deposition, enabling time-resolved measurements of key plasma parameters, including ion density, electron temperature, and ion flux.

References:
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[2] N. Holtzer *et al.*, *Surf. Coat. Technol.*, 2014, *250*, 32-36
[3] L. J. van der Pauw, *Philips Res. Rep.*, 1958, *13*, 1-9
[4] P. Sezemsky *et al.*, *Plasma Sources Sci. Technol.*, 2019, *28*, 115009

High-fidelity detection of scattering amplitude and phase

Kateřina Jiříková

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The field of light microscopy has undergone significant advances over the last few decades, enabling increased sensitivity and enhanced quantitative analysis for investigating nanoscopic structures. Among these advancements, interferometric scattering microscopy (iSCAT) has emerged as a widely used ultra-sensitive microscopy technique, recognised for its high precision in single-molecule localisation and its exceptional suitability for studying the dynamics of nano-objects [1]. iSCAT has advanced to the point where it can observe the dynamics of individual proteins and provide high-resolution quantitative measurements of molecular mass and interactions [2,3]. A key strength of iSCAT lies in its inherent sensitivity to phase changes in scattered light, which can reveal valuable information about the structural and dynamic features of a sample. However, conventional iSCAT setups face challenges in extracting phase information from the detected intensity. To address this limitation, we present a novel iSCAT approach that integrates a newly developed photothermal spatial light modulator (PT-SLM) for quantitative phase detection [4,5]. By modulating the phase shift between the scattered and reference light, this innovative approach enables the separation and extraction of amplitude and phase, which are typically inseparable in intensity measurements. We use this method to study the effect of surface roughness on the measured image and conclude that even sub-nanometre irregularities significantly affect the iSCAT contrast. These findings underscore the importance of accounting for surface roughness in quantitative iSCAT analyses, particularly when aiming for precise contrast interpretation and measurement accuracy.

[1] Palounek et al., 2024, *ACS Photonics*
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[3] Piliarik, Sandoghdar, 2014, *Nat. Communications*
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Pathogen-on-a-Chip: Impedance-Based Detection of Biofilm Formation and Inhibition by *Staphylococcus aureus* and *Staphylococcus epidermidis*

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Biofilms are bacterial communities embedded in an extracellular matrix (ECM) which makes them resistant to antimicrobial treatments. [1] Detection of biofilm is important for early treatment; however, traditional methods are rather complex, tedious or time-consuming. Electrochemical impedance spectroscopy (EIS) has gained importance due to its ability to detect and monitor biofilms sensitively and non-destructively. [2] Our research focused on detecting biofilm formation and inhibition by *Staphylococcus aureus* and *Staphylococcus epidermidis* by evaluating charge transfer resistance (R_{ct}) obtained from the fitted data of an equivalent electrical circuit using poly-L-lysine (PLL) modified two-electrode gold printed circuit board (PCB) electrodes. Presence, roughness or height profiles [3] of the biofilm were further evaluated by optical microscopy with safranin staining and atomic force microscopy. The mean R_{ct} values for the control, *S. epidermidis* biofilm, and *S. aureus* biofilm were ~30,000 Ω, ~120,000 Ω, and ~90,000 Ω, respectively, while R_{ct} values upon antibiotic treatment were ~40,000 Ω for *S. epidermidis* and ~30,000 Ω for *S. aureus*. Study showed that *S. aureus* biofilm was rougher, more heterogeneous and had less ECM than *S. epidermidis* which might be caused different signals of impedance. Preliminary results of a simply configured and cost-effective impedance-based biosensor have shown sensitive detection of bacterial biofilm and inhibition. This offers a promising tool for detecting biofilm and evaluating antimicrobial agents.

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[3] R. Obořilová et al., *Nanoscale*, 2021, 13, 13538

Black Metal Thin Films via PVD Methods for Gas Sensing Applications

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In recent years, porous metallic layers have captured the attention in the scientific community due to their unique characteristics arising from their delicate surface structure. Especially within the field of gas sensors, nanostructured, or black, metal layers are demonstrating promising potential, as they can further amplify the sensing capabilities of such devices. Various metals can be prepared in highly nanostructured forms to increase their surface to volume ratio, consequently raising sensitivity of gas sensors to various analytes. The enhanced porosity of black metal layers provides numerous additional bonding sites for gas analyte particles to adsorb onto. One method of producing these metal layers involves depositing the source material (such as gold, silver, or aluminum) using physical vapor deposition techniques. In this study, we outline the fabrication of these layers through magnetron sputtering, pulse laser deposition and thermal evaporation methods. Subsequently, we investigated the usage of these films as active layers of gas sensors based on the principle of chemiresistors, meaning devices that change their output quantity (electrical resistance or impedance) depending on a specific chemical stimulus - i.e. the presence of the detected chemical in the environment being analyzed. The model response of a chemiresistor for a gas analyte can be seen on Fig.1.

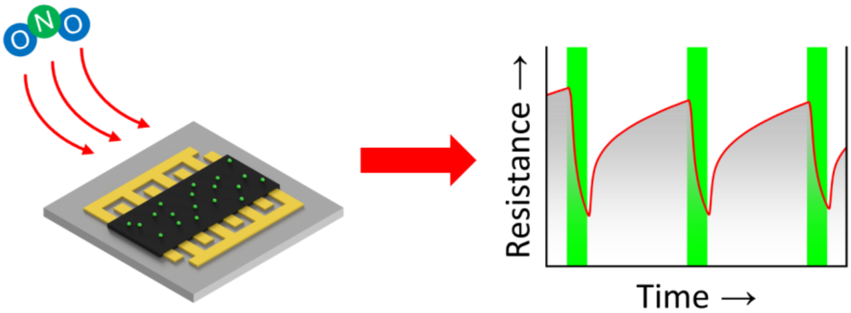

Figure 1: Schematic of the sensor equipped by interdigital electrodes with a black metal active layer and a representation of the sensors' response to a gas analyte.

Silver-Nanodiamond Complexes with Tunable Light-Matter Interaction: Self-Assembly, Microstructure and Plasmonic Enhancement

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The synergic interaction between plasmonic metal nanoparticles (mNPs) and nanodiamonds (NDs) offers a versatile platform for tuning light-matter interactions at the nanoscale, with a strong potential for biomedical applications, particularly in biosensing. Our research explores mNP-ND nanocomplexes created from colloidal mixtures of well-defined particles through self-assembly. In close collaboration with FZU AV ČR in WP1, we systematically investigate their formation mechanisms, structures, and interactions, with a focus on plasmonic properties. We employ spectroscopic, computational, and microscopic imaging methods. The nanocomplexes consist of 20 nm particles of silver (AgNPs) and either 4 nm detonation nanodiamonds (DNDs) [1] or 50 nm high-pressure high-temperature (HPHT) nanodiamonds [2], hydrogenated (HNDs) [3] or oxidized (ONDs) [4]. Our recent works show that water-diluted DNDs spontaneously aggregate into lace-like networks [5] that entangle individual AgNPs, forming stable nanocomplexes with robust interparticle interactions. On the other hand, larger functionalized HPHT NDs, regardless of their polarity, attract smaller AgNPs via electrostatic and/or spontaneous surface chemical bonding. Imaging by SEM, TEM and RF electromagnetic simulations show that AgNPs thereby maintain an approximate gap of 3 nm from the NDs, enabling the electromagnetic field modulation. AgNPs also do not aggregate on NDs, leading to a stable or small 8 nm redshifted plasmonic wavelength due to weak interaction. In all systems, we observe consistently that low AgNP concentrations enhance plasmonic absorption (up to +124%) of the nanocomplexes, while higher concentrations suppress it (down to -49%). This effect is attributed to charge redistribution mediated by NDs and electromagnetic interference in AgNPs. The inherent formation simplicity and controllable plasmonic properties make this nanodiamond platform suitable for designing advanced plasmonic sensors and enhancing the functionality of nanophotonic and optoelectronic devices.

References:

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Design and Fabrication of DNA Origami Cubes as Model Systems for Nanofluidic Scattering Microscopy

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DNA origami enables the precise self-assembly of complex nanostructures by folding a long single-stranded DNA scaffold with the help of multiple short staple strands, offering versatile platforms for applications in biosensing, drug delivery, and nanophotonics [1,2]. In this project, DNA nanocubes were developed as model systems for label-free nanofluidic scattering microscopy [3]. Their sequences were computationally optimized for reversible assembly at room temperature, enabling real-time monitoring of structural dynamics. Stability and conformational behavior were validated through OxView and oxDNA simulations [4,5,6]. The well-defined geometry of the nanocubes facilitates scattering-based measurements to determine molecular weight, hydrodynamic radius, and to track conformational changes, aggregation, and biomolecular interactions at the single-molecule level. Assembled structures were purified using agarose gel extraction and/or polyethylene glycol precipitation. Preliminary experiments using a nanofluidic microscope confirmed the suitability of these nanocubes as a proof-of-concept system for scattering-based single-molecule analysis. The association and dissociation rate constants obtained from microscopy will be compared with those determined by SPR, where the cubes are immobilized on the surface of a gold chip in combination with antifouling polymer brushes.

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Summary of the most important results of the JLO Applied Optics Group

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The talk presents selected recent achievements of the JLO Applied Optics Group. The first is the development of a CNC sub-aperture machining process for glass surfaces of optical components. These components are now manufactured at JLO using a combination of conventional and CNC-based technologies, serving as both transmissive and reflective elements in optical assemblies for particle and astroparticle physics experiments. Traditional grinding followed by polishing is not suitable for producing more complex shapes, such as aspheres and freeforms. Therefore, significant effort is being invested into developing a complete CNC-based process capable of delivering surface quality—both in terms of form and roughness—comparable to that of classical methods, for components with transverse dimensions up to 1 meter. This requires extensive testing and optimization of CNC milling and polishing parameters.

The second topic covers the development of a glass gravity slumping process into ceramic moulds. This technique is used at JLO to fabricate the most common type of concave primary mirrors for telescopes used in astroparticle experiments. Gravity slumping is particularly advantageous for the relatively fast and cost-effective shaping of large optical surfaces, as it eliminates the need to remove substantial volumes of material as in subtractive processes. Moreover, it enables the preparation of large, thin substrates (on the order of millimetres thick) suitable for subsequent optical coating.

The third area of development is the modification of the Swing Arm Profilometer (SAP), based on a European patent [1]. The upgraded version represents the first functional prototype of a unique non-contact metrology device capable of measuring both irregularity and spherical deviation of large optical surfaces up to 1 meter in diameter. The SAP is intended for use in both in-process and final inspection of finely ground, polished, or coated optical elements.

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