Biophotonics and optofluidic

Department of Microphotonics

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THEMATIC RESEARCH FOCUS

Research area

- Optics
- Laser spectroscopy
- Biophotonics
- Nanophotonics
- Lab-on-a-chips
- Optofluidics

Excellence

- Applications of focused laser beams (optical tweezers, optical cell sorters)
- Raman micro-spectroscopy combined with optical manipulations (Raman tweezers)
- Manufacturing of tailored microfluidic chips

Mission

Our main goal is to design and develop analytical techniques based on microfluidic and Raman spectroscopy to solve emerging tasks targeted on basic and applied biological research ranging from microorganisms to enzymes.

UP-TO-DATE ACTIVITIES

Research orientation

- Optical trapping
- Design of novel microfluidic chips for biological research
- Characterization of living microorganisms (e.g. bacteria, yeast and algae cells) using Raman microspectroscopy, Raman tweezers and microfluidic chips.
- Optical monitoring of chemical reactions running in emulsion droplets and lab-on-a-chip

Main capabilities

Basic research

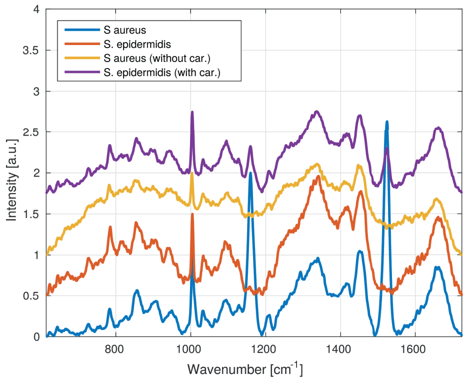
- Determination of selected chemical content in living microorganisms using Raman microspectroscopy combined with optical micromanipulation and microfluidic techniques

Applied research

- Design and manufacturing of microfludic chips
- Monitoring of polymers inside the cells with industrial biotechnological applications
- Identification of bacteria with clinical applications

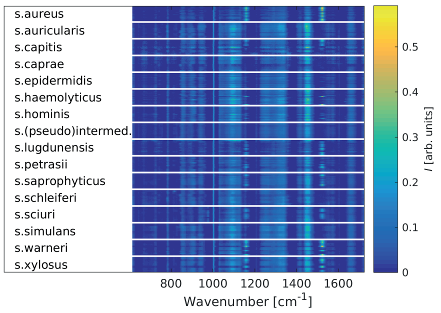
Innovations

- Tailored microfluidic chips for clinical investigations of microorganisms



Raman spectra of bacteria showing the differences between the strains.

2D presentation of Raman spectra for different bacterial strains.



Sub-fields of group activities

- Optical microscopy
- Microtechnology, nanotechnology
- Biophotonics
- Cell biology
- Biochemistry
- Laser spectroscopy
- Microfluidics
- Lab-on-a-chip systems
- Microbiology

KEY RESEARCH EQUIPMENT

List of devices

- Renishaw In Via Reflex Raman microspectrometer
- Raman tweezers made by the research team
- Optical cell sorters made by the research team
- Fast CCD cameras (thousands fps)

ACHIEVEMENTS

Awards

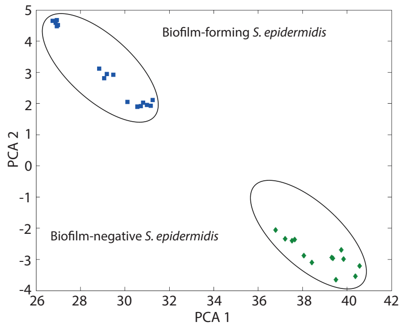
- Zdeněk Pilát was awarded the best Ph.D. Thesis in 2015 by the Czechoslovak Microscopy Society

Publications

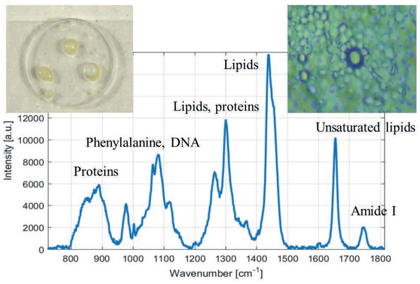
We are in the forefront of application of Raman spectroscopy to clinical praxis and biotechnological/industrial applications. Our latest research on identification and differentiation of bacteria is well recognized in scientific community and microbiological labs. Moreover, we contributed to the basic and applied research of polymer containing microorganisms and also in monitoring of chemical reactions directly on the microfluidic chip. We published more than 15 papers in impacted journals with very good citation response in the period 2013–2017. Combination of Raman microspectroscopy and optical tweezers offers a unique tool that provides contactless and nondestructive manipulation and diagnostics of living microorganisms. Optical tweezers provides 3D manipulation with objects and Raman microscopy represents one of a few contactless and nondestructive methods that provides information about the chemical bonds inside microobjects (even living cells).

Identification and differentiation of bacteria and yeast

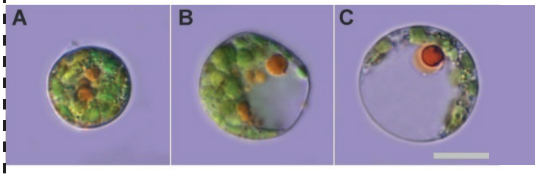
- D. Procházka, M. Mazura, O. Samek, K. Rebrošová, P. Pořízka, J. Klus, P. Procházková, J. Novotný, K. Novotný, J. Kaiser: "Combination of laser-induced breakdown spectroscopy and Raman spectroscopy for multivariate classification of bacteria", Spectrochimica Acta Part B 139, 6-12, 2018.
- K. Rebrošová, M. Šiler, O. Samek, F. Růžička, S. Bernatová, V. Holá, J. Ježek, P. Zemánek, J. Sokolová, P. Petráš: "Rapid identification of staphylococci by Raman spectroscopy", Scientific Reports 7, 14846, 2017.
- K. Rebrošová, M. Šiler, O. Samek, F. Růžička, S. Bernatová, J. Ježek, P. Zemánek, V. Holá: "Differentiation between Staphylococcus aureus and Staphylococcus epidermidis strains using Raman spectroscopy", Future Microbiology 12, 881-890, 2017.
- O. Samek, S. Bernatová, J. Ježek, M. Šiler, M. Šerý, V. Krzyžánek, K. Hrubanová, P. Zemánek, V. Holá, F. Růžička: "Identification of individual biofilm-forming bacterial cells using Raman tweezers", J. Biomed. Opt. 20, 051038, 2015.



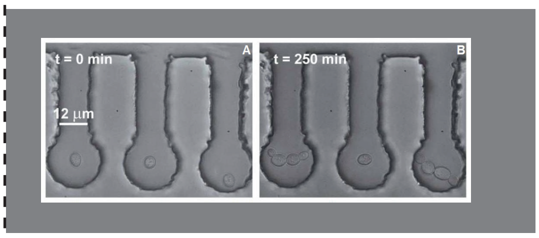
PCA plot demonstrating differentiation of the biofilm-forming and biofilm-negative bacterial staphylococcal strains.



Raman spectrum of an oil drop produced by yeast Metschnikowia. Left inset shows pipetted sample, magnified detail is shown on the right inset.



Living alga cellsTrachydiscus minutus cultivated at different light conditions and having different contents of lipid bodies.



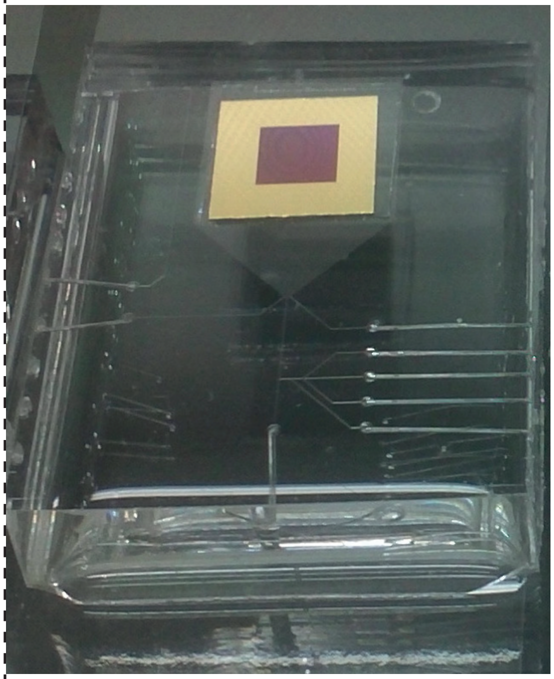
Microfluidic chambers used for separation of cells out of the main channel. Cells are introduced to the chamber using the optical tweezers.

– O. Samek, K. Mlynáriková, S. Bernatová, J. Ježek, V. Krzyžánek, M. Šiler, P. Zemánek, F. Růžička, V. Holá, M. Mahelová: "Candida parapsilosis biofilm identification by Raman spectroscopy", Int. J. Mol. Sci. 15, 23924-23935, 2014.
– K. Mlynáriková, O. Samek, S. Bernatová, F. Růžička, J. Ježek, A. Haroniková, M. Šiler, P. Zemánek, V. Holá: "Influence of culture media on microbial fingerprints using Raman spectroscopy", Sensors 15(11), 29635-29647, 2015.
– S. Bernatová, O. Samek, Z. Pilát, M. Šerý, J. Ježek, P. Jákl, M. Šiler, V. Krzyžánek, P. Zemánek, V. Holá, M. Dvořáčková, F. Růžička: "Following the mechanisms of bacteriostatic versus bacericidal action using Raman spectroscopy", Molecules 18(11), 13188-13199, 2013.

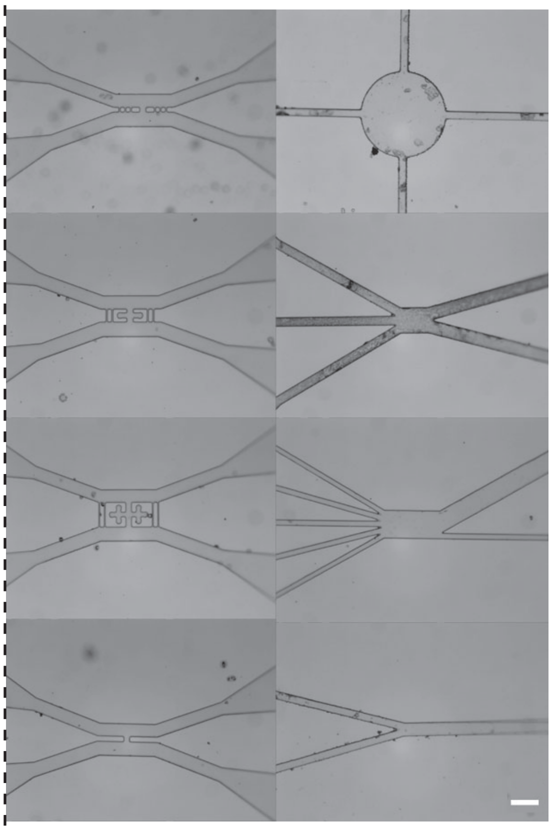
Applications to microorganisms containing polymers and algae

– S. Obruča, P. Sedláček, F. Mravec, V. Krzyžánek, J. Nebesářová, O. Samek, D. Kučera, P. Benešová, K. Hrubanová, M. Milerová, I. Márová: "The presence of PHB granules in cytoplasm protects non-halophilic bacterial cells against the harmful impact of hypertonic environments", New Biotechnology 39, 68-80, 2017.
– Z. Pilát, A. Jonáš, J. Ježek, P. Zemánek: "Effects of Infrared Optical Trapping on Saccharomyces cerevisiae in a Microfluidic System", Sensors 17, 2640, 2017.
– F. Mravec, S. Obruča, V. Krzyžánek, P. Sedláček, K. Hrubanová, O. Samek, D. Kučera, P. Benešová, J. Nebesářová: "Accumulation of PHA granules in Cupriavidus necator as seen by confocal fluorescence microscopy", FEMS Microbiology Letters 363(10), 2016.
– S. Obruča, P. Sedláček, V. Krzyžánek, F. Mravec, K. Hrubanová, O. Samek, D. Kučera, P. Benešová, I. Márová: "Accumulation of Poly(3-hydroxybutyrate) helps bacterial cells to survive freezing", PLoS ONE 11, e0157778, 2016.
– S. Obruča, P. Sedláček, F. Mravec, O. Samek, I. Márová: "Evaluation of 3-hydroxybutyrate as an enzyme-protective agent against heating and oxidative damage and its potential role in stress response of poly (3-hydroxybutyrate) accumulating cells", Appl Microbiol Biotechnol 100, 1365-1376, 2016.
– P. Pořízka, P. Procházková, D. Procházka, L. Sládková, J. Novotný, M. Petrilak, M. Brada, O. Samek, Z. Pilát, P. Zemánek, V. Adam, R. Kizek, K. Novotný, J. Kaiser: "Algal biomass analysis by laser-based analytical techniques—A review", Sensors 14, 17725-17752, 2014.
– Z. Pilát, J. Ježek, M. Šerý, M. Trtílek, L. Nedbal, P. Zemánek: "Optical trapping of microalgae at 735-1064 nm: Photodamage assessment", Journal of Photochemistry and Photobiology B: Biology 121, 27-31, 2013.
– Z. Pilát, S. Bernatová, J. Ježek, M. Šerý, O. Samek, P. Zemánek, L. Nedbal and M. Trtílek: "Raman microspectroscopy of algal lipid bodies: beta-carotene quantification", Journal of Applied Phycology 24, 541-546, 2012.
– P. Pořízka, D. Procházka, Z. Pilát, L. Krajcarová, J. Kaiser, R. Malina, J. Novotný, P. Zemánek, J. Ježek, M. Šerý, S. Bernatová, V. Krzyžánek, K. Dobranská, K. Novotný, M. Trtílek, O. Samek: "Application of laser-induced breakdown spectroscopy to the analysis of algal biomass for industrial biotechnology", Spectrochimica Acta Part B: Atomic Spectroscopy 74-75, 169-176, 2012.

Optical monitoring of biochemical reactions running in emulsion droplets in microfluidic chips



Microfluidic chip with Au/Si substrate for surface enhanced Raman spectroscopy (SERS) of low concentrations of various halogenated hydrocarbons.



Various microchannel designs for flow routing, cell sorting, and storage.

MAIN COLLABORATING PARTNERS

Collaboration with academic partners

- Brno University of Technology (Brno, CZ)
- Consiglio Nazionale delle Ricerche (Messina, IT)
- Institute of Experimental Physics, Slovak Academy of Sciences (Košice, SK)
- Masaryk University (Brno, CZ)
- Universität für Bodenkultur (Wien, Austria)
- University of Graz (Graz, Austria)
- University of Life Sciences (As, Norway)
- University of Naples Frederico II (Naples, IT)
- University of Jena (Jena, Germany)
- IPHT Jena (Jena, Germany)

Collaboration with companies

- Meopta (Přerov, CZ)
- Photon Systems Instruments (Drásov, CZ)

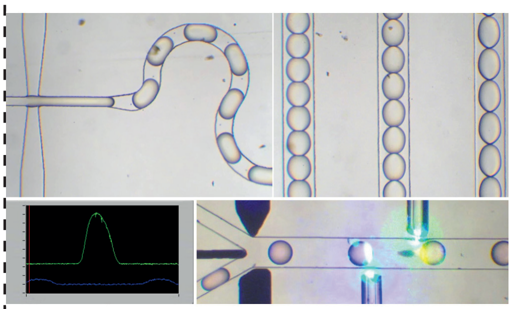
EXPECTATIONS

Offers

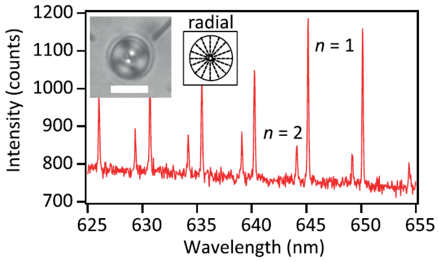
- We offer collaboration in the areas of our expertise.
- Partnership in international projects
- Custom manufacturing of microfluidic chips.

Requirements

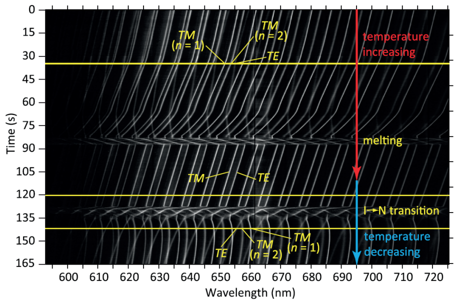
We would like to cooperate with academic partners as well as companies in the fields of optics, biophotonics, biotechnology, microtechnologies and applications of microfluidic chips.



An example of droplet microfludics. Top left: droplet generation, top right: parallel channels, bottom: fluorescent characterization of the droplet content.



WGM spectra from thermally tuned optically trapped liquid crystal droplet resonator. Scale bar: 10 um



Thermal tuning of WGM emission of liquid crystal droplets, mapping of the transitions between isotropic and nematic phases.