Applied and Integrated Photonics Group

Department of Microphotonics

ISI CAS Institute of Scientific Instruments The Czech Academy of Sciences

R&D PROFILE

Research area

- Optical design
- Precise mechanics
- Optical lithography
- Spectroscopy
- Multispectral and hyperspectral imaging
- Integrated photonics
- Machine learning and artificial intelligence
- Surface topography and local mechanical properties

Excellence

- Opto-mechanical design of optical instruments
- Two-photon lithography techniques on in house developed systems
- Hyperspectral microscopy and imaging spectrography systems
- On-demand design and manufacturing of imaging and spectroscopy systems
- Photonics system and integrated optics design and manufacturing

Mission

Using our knowledge, we design and fabricate micro-optical elements including devices for their production.

Integration of micro-optics, photonic optics and bulk optics into scientific instruments opens new possibilities to develop new classes of systems for understanding more about matter interaction and allows us complex investigation of biological and chemical processes in the samples and also miniaturization of the instruments.

Currently, our team is concentrated on the development of advanced imaging and hyperspectral imaging systems using specially designed optical elements. These are widely applicable in plant agriculture and microbiology.

We also work on image processing software to analyze morphological composition at a sub-micrometer scale. We process large datasets acquired by our instruments using machine learning algorithms.

Illustration photo of a hyperspectral camera being used in the field.

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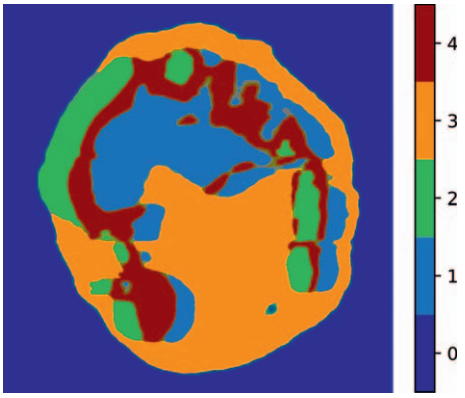
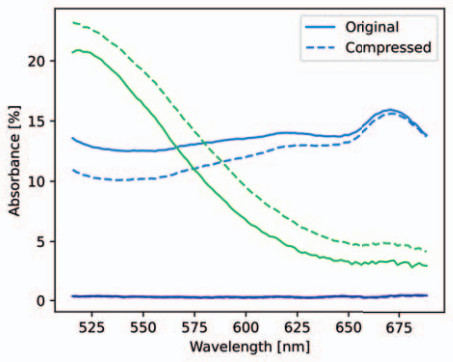


Hyperspectral imaging allows us to locate areas with a similar spectral response.

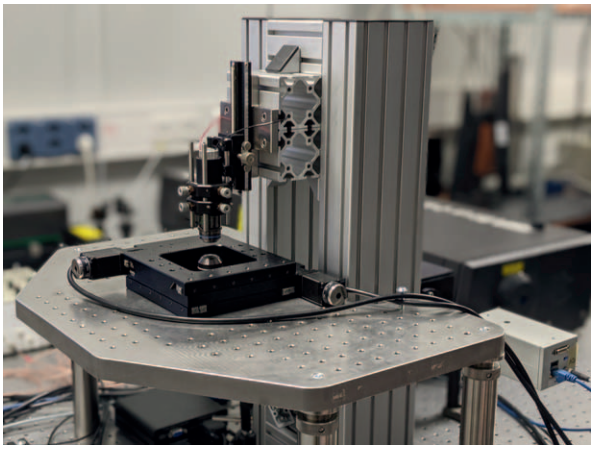


Hyperspectral data can be compressed using ML methods without significant loss of spectral attributes.

UP-TO-DATE ACTIVITIES

New technologies in hyperspectral imaging

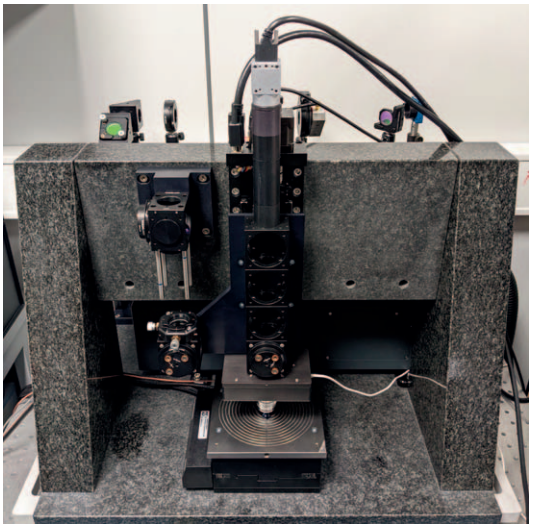
- Development of imaging spectrographs with submicron spectral resolution
- Development of snapshot imaging spectrographs
- Design of MEMS based spectrographic systems
- Software development based on machine learning and artificial intelligence that allow fast spatial and spectral recognition of objects
- Hyperspectral imaging is useful for inline sorting and quality control



Developed hyperspectral microscope for cell examination.

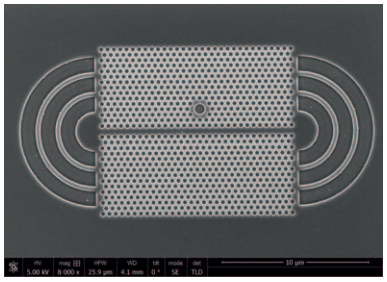
Single and two-photon lithography

- Single photon large volume lithography system with a digitally addressable projection system for biological and material applications
- High accuracy positioning of sample stage and objective using an interferometric closed loop
- Precision two-photon lithography system with acoustooptics laser beam steering system for very fast and accurate microstructures writing
- Development of writing strategies and special techniques for high-volume, high-resolution printing
- Interference and holographic recording of microstructures using modulators and DLP technology
- Beam shaping of writing beam by spatial modulators
- Refraction and diffraction optics design and manufacturing

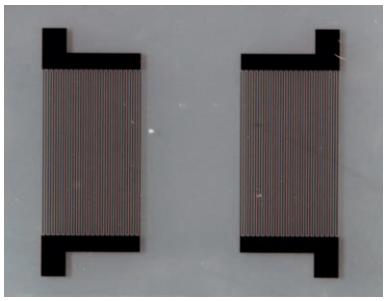


Experimental two-photon lithography system.

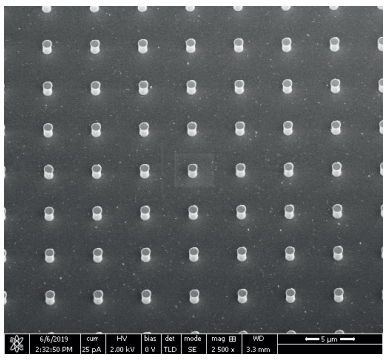
Structure of lion prepared by two photon lithography system. With permission of IQSnano.



Photonic element designed to trap particles (SEM image).



Gold electrodes on $LiNbO_3$ designed to generate standing surface acoustic wave (SSAW).

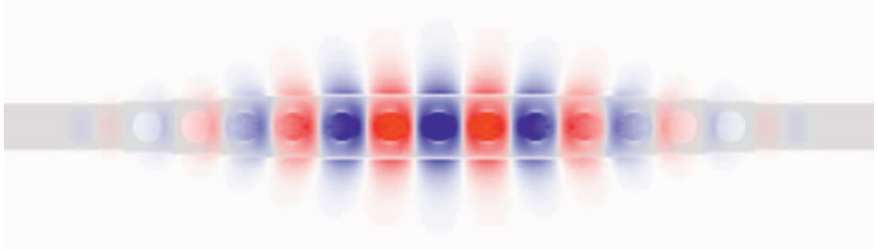


Sub-micrometer columns, prepared into silicon by reactive ion etching.

Applied and integrated photonics

- Compact optical tweezers system with MEMS steering optics and optomechanics for biomedical applications
- The use of photolithographic methods, wet and dry etching to produce optical elements, microfluidics and metasurfaces
- Microchip for optical trapping of micro-objects under low pressure
- Metaoptics structures for aberration-free imaging and spectroscopy systems
- Inspection by Scanning Probe Microscopy with emphasis on the surface topography of prepared nanostructures and films & coatings
- Determination of mechanical properties such as elastic modulus, hardness or film adhesion by nanoindentation measurements and scratch testing
- Microfluidic acoustic wave based sorting chips
- Arbitrary shaped optical gratings and micro-optical elements.

We are involved in achieving synergy between optomechanics and integrated photonics to create systems with better functionality and properties.



Electric field mode profile of photonic crystal nanobeam cavity for optical trapping.

KEY RESEARCH EQUIPMENT

List of devices

- Hyperspectral VNIR and SWIR microscope system
- Single photon lithography system
- Two-photon lithography system
- Deep reactive ion etching system
- Spin coating system, wet benches, hot plates, class ISO 2 cleanroom facility
- Digital Light Processing printer, FDM printer, CNC machine
- Optical metrology equipment
- Lasers, microscopes, precision motorized stages, optics tables, etc

ACHIEVEMENTS

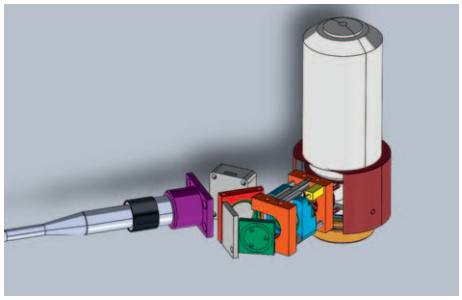
Articles

- PLICHTA, T., R. ZAHRADNICEK and V. CECH. 2022. *Surface topography affects the nanoindentation data.* Thin Solid Films. 745.
- PLICHTA, T., V. SIRJOVOVA, M. ZVONEK, G. KALINKA and V. CECH. 2021. *The adhesion of plasma nanocoatings controls the shear properties of GF/polyester composite.* Polymers. 13(4).
- TRAEGAARDH, J., T. PIKALEK, M. SERY, T. MEYER, J. POPP and T. CIZMAR. 2019. *Label-free CARS microscopy through a multimode fiber endoscope.* Optics Express. 27(21).
- JAKL, P., T. CIZMAR, M. SERY and P. ZEMANEK. 2008. *Static optical sorting in a laser interference field.* Applied Physics Letters. 92(16).
- CIZMAR, T., M. SILER, M. SERY, P. ZEMANEK, V. GARCES-CHAVEZ and K. DHOLAKIA. 2006. *Optical sorting and detection of submicrometer objects in a motional standing wave.* Physical Review B. 74(3).

Utility model

- Compact optical tweezers modules compatible with a majority of optical microscopes (utility model awarded in cooperation with Meopta-Optika)

Compact device for creating optical tweezers attachable to a Raman microscope.



CAD model of optical tweezers with MEMS mirror used for beam steering.

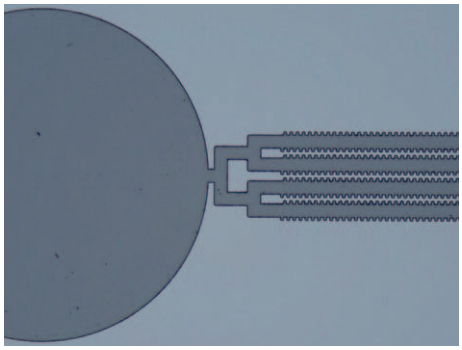
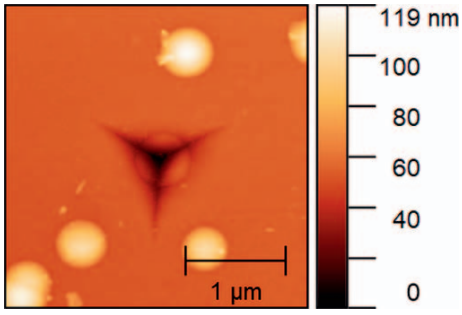
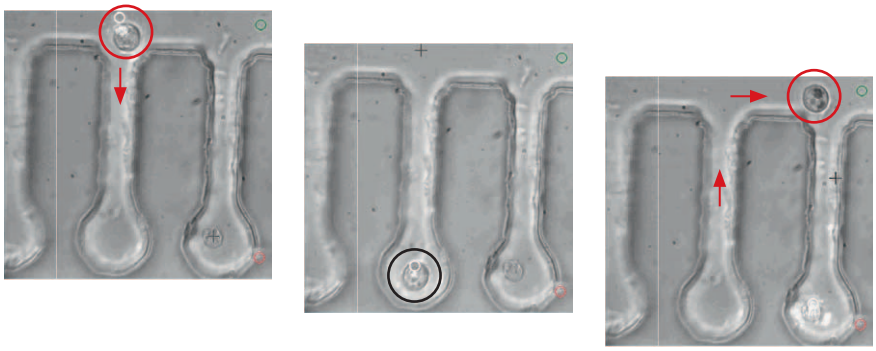


Image of a microfluidic channel observed by optical microscope.



Surface topography of indent residual imprint observed by AFM on top of a-CSi:H grain.



Algae cells inside incubation microfluidic channel can be manipulated by steerable optical tweezers system of our design. Red arrows indicate the direction of movent induced by the optical tweezers.

MAIN COLLABORATING PARTNERS

Collaboration with academic and industrial partners

- Brno University of Technology (Brno, CZ)
- Charles University (Prague, CZ)
- Consiglio Nazionale delle Ricerche (Messina, IT)
- Masaryk University (Brno, CZ)
- Institute of Experimental Physics, Slovak Academy of Sciences (Košice, SK)
- Photon Systems Instruments (Drásov, CZ)
- IQS nano (Brno, CZ)
- Meopta (Přerov, CZ)

EXPECTATIONS

Offers

We offer to share our expertise in the areas of spectroscopy, imaging, optical lithography, applied and integrated optics.

Requirements

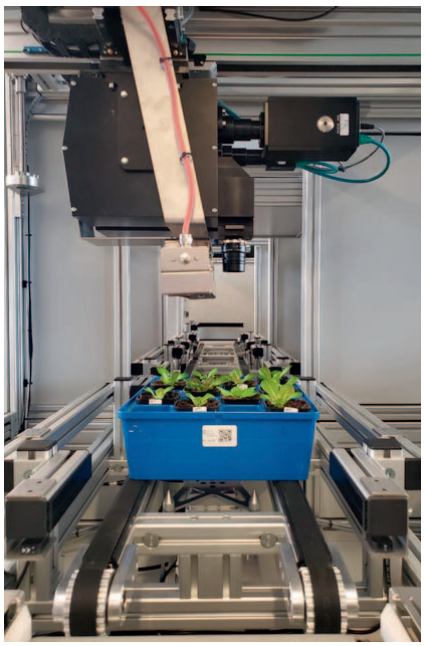
We look for cooperation with academic and industrial partners in the fields of spectroscopy, micro and nano optics development and manufacturing.

FUNDING

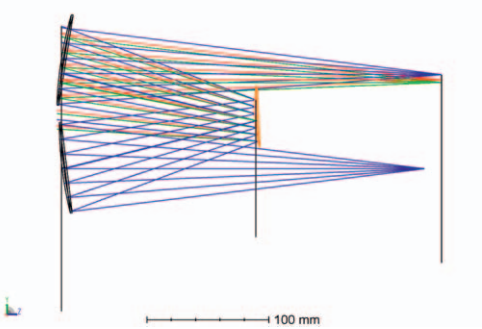
HyPerSpec - Development of Hyperspectral Camera for Biotechnology Applications and Element Analysis, FV40455 Ministry Industry and Trade CR

Technology for Advanced Optics and Its Industrial Application, CZ.01.1.02/0.0/0.0/ /19_262/0020294 Ministry Industry and Trade CR.

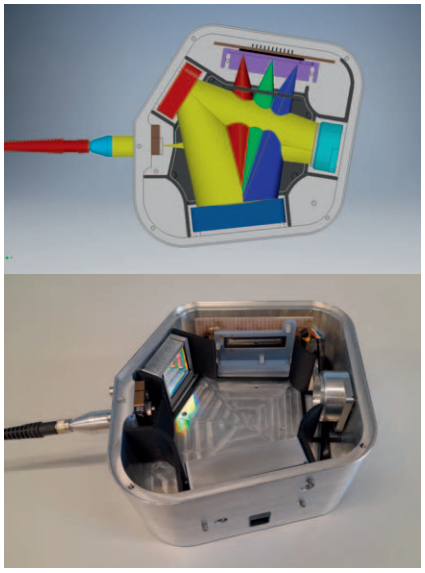
Multispectral images provide information about object refl ectance in wide spectral bands. By comparing their values, we can monitor plant vitality and stress.



Hyperspectral camera system used for inline monitoring of plant vitality based on spectral reflectance.



Optical design simulation of hyperspectral camera.



Custom-designed Czerny-Turner spectrometer from off the shelf components.