

MISSION

Development of new diagnostic methods, novel instrumental principles and advanced technologies from the macroscopic to the quantum regimes enabling significant progress in the understanding of inanimate and living nature and the practical application thereof.

PRINCIPAL ACTIVITIES

- Multidisciplinary research and advanced engineering combining the fields of magnetic resonance spectroscopy and tomography, electron microscopy and microanalysis, laser based spectroscopy, imaging, manipulation, and nanometrology, acquisition and processing of biosignals and large data, cryogenics, electron and laser beam technologies
- Dissemination of scientific results in respected journals, proceedings etc.
- Training of young researchers in multidisciplinary and world-class research
- Involvement of university students in ISI scientific activities and the provision of doctoral study programmes in cooperation with universities
- Raising the level of knowledge and education via popularization activities focused on public and students, promoting science and technology through direct projects with high and basic schools
- Technology transfer of applicable results to industry, education and health promoting international cooperation within the scope of ISI activities
- Organization of scientific meetings, conferences and seminars at national and international level
- Providing infrastructure for research

Institute of Scientific Instruments
of the CAS, v. v. i.

Královopolská 147, 612 64 Brno
Czech Republic

Phone: +420 541 514 111

E-mail: institute@isibrno.cz

www.isibrno.cz

VAT number: CZ68081731

Data Box ID: 8c4nph

MAIN CONTACT PERSONS

Director: Dr. Ilona Müllerová, DrSc.

Phone: +420 541 514 204

E-mail: director@isibrno.cz

Deputy Director for Research:

Prof. Pavel Zemánek

Phone: +420 541 514 202

E-mail: Pavel.Zemanek@isibrno.cz

Deputy Director for Executive Affairs:

Dr. Bohdan Růžička, MBA

Phone: +420 734 313 043

E-mail: Bohdan.Ruzicka@isibrno.cz



Main entrance of ISI CAS.

STATISTICS 2018

Financial resources in thousands CZK

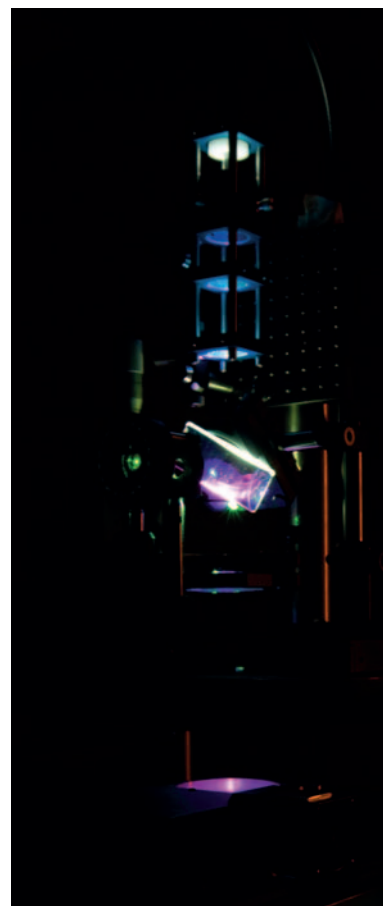
- **Resources for expensive equipment and construction: 69767**
 - from The Czech Academy of Sciences: 27204
 - from Czech projects: 42563
- **Operating resources: 198788**
 - from The Czech Academy of Sciences: 71973
 - from Czech projects: 123739
 - from foreign projects: 3076
- **Revenue from contractual research: 11985**
- **Number of employees: 184 (full time equivalent FTE)**
- **Number of researchers: 103 FTE**
- **Number of PhD students: 27 FTE**
- **Number of papers in scientific journals with impact factor: 60**
- **Number of filed patents or utility models: 9**

RECENT AWARDS

- 2018** Radovan Smíšek won in the competition "Left Bundle Branch Block Initiative" organized by the International Society for Computerized Electrocardiology
- 2017** Josef Halámek was awarded The František Křižík Honorary Medal for Merit in the Technical Sciences and for the Implementation of Results of Scientific Research
- 2017** ISI, FNUSA-ICRC and University of Rochester team led by Filip Plešinger was awarded Clinical Needs Translational Award
- 2017** Tomáš Pikálek and his supervisor Zdeněk Buchta were awarded Werner von Siemens Award 2016 for "The best diploma thesis"
- 2017** Radim Skoupý was awarded Thermo Fisher - Czechoslovak Microscopy Society Fellowship for young researchers
- 2016** The team of Vilém Neděla was awarded Wabunshisyo award by the Japanese Society of Microscopy
- 2016** Zdeněk Pilát was awarded the price of Czechoslovak Microscopy Society for "The best PhD thesis employing microscopic techniques"
- 2015** The team of Pavel Jurák was awarded the first and the second prize in "Computing in Cardiology/Physionet Challenge 2015"
- 2015** Kamila Hrubanová was awarded Thermo Fisher – Czechoslovak Microscopy Society Fellowship for young researchers
- 2014** The team of Pavel Zemánek was awarded Werner von Siemens Award 2013 for "The most significant result of fundamental research"
- 2014** Miroslav Horáček was awarded the Vox Populi Award "Art in Microscopy" of the 18th International Microscopy Congress
- 2013** Ilona Müllerová was awarded the national prize Czech Head – Inventions
- 2013** The team of Ondřej Číp was awarded Werner von Siemens Award 2012 for "The most important result of development/innovation"
- 2005** Armin Delong was awarded the national prize Czech Head

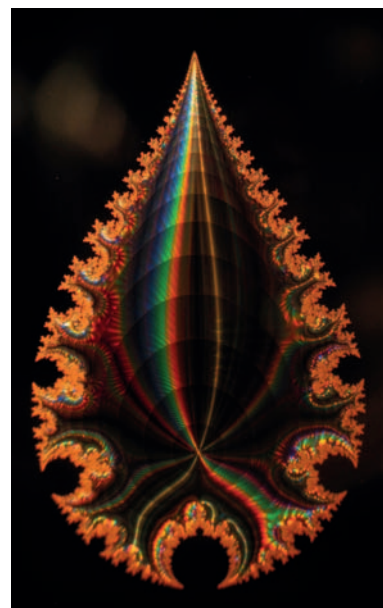
RUNNING LARGER PROJECTS

- 2018–2020** *Centre of Electron and Photonic Optics*. Principal investigator Ilona Müllerová, supported by National Centres of Competence program of the Technology Agency of the Czech Republic (TACR)
- 2018–2021** *Large Volume Metrology Applications*. ISI investigator Ondřej Číp supported by EURAMET
- 2018–2021** *Coulomb Crystals for Clocks*. Ondřej Číp, supported by EURAMET

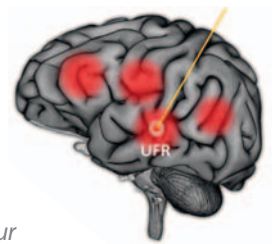
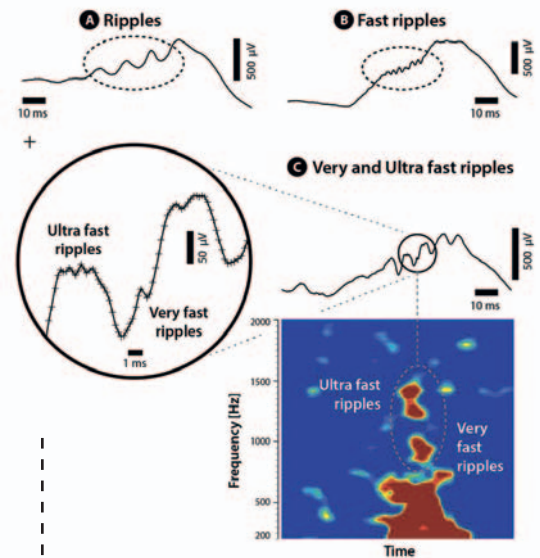


Experimental realization of optical tractor beam.

Relief structure created by a single forked line in a nanometre resolution performing both first-order diffractive colours and a structural colour at its edge.



- 2017–2022** *Holographic Endoscopy for in vivo Applications.* Tomáš Čižmár, supported by Ministry of Education Youth and Sports of the Czech Republic (MEYS), European Regional Development Fund (ERDF)
- 2017–2020** *Modernization and Support of Research Activities of the National Infrastructure for Biological and Medical Imaging – Czech-Biolmaging.* Zenon Starčuk, supported by MEYS, ERDF, ISI
- 2017–2019** *CLOCK NETWORK Services: Strategy and Innovation for Clock Services over Optical-fibre Networks.* Ondřej Číp, supported by H2020
- 2017–2019** *Applications of Advanced Interferometric Methods for Surface Measurements in Optical Industry.* Josef Lazar, supported by Ministry of Industry and Commerce of the Czech Republic (MIC), ERDF
- 2017–2019** *High-tech Detection Systems for Electron Microscopy.* Vilém Neděla, supported by MIC, ERDF
- 2017–2019** *Advanced Technology for Non-invasive Diagnostics of Heart Electromechanics – VDI Monitor.* Pavel Jurák, supported by MIC, ERDF
- 2017–2019** *Optical Sensor Systems Calibration and Specialty Sensors for Nuclear Power Plants.* Břetislav Mikel, supported by MIC, ERDF
- 2014–2018** *Sources, Interaction with Matter, Detection and Analysis of Low Energy Electrons 2.* Ilona Müllerová, supported by EC FP7
- 2014–2018** *Center of Excellence for Classical and Quantum Interactions in Nanoworld.* Pavel Zemánek, supported by the Czech Science Foundation
- 2014–2018** *ALISI – Centre of Advanced Diagnostic Methods and Technologies.* Pavel Zemánek, supported by MEYS
- 2012–2019** *Advanced Microscopy and Spectroscopy Platform for Research and Development in Nano and Microtechnologies – AMISPEC.* Josef Lazar, supported by Competence Centres program of TACR
- 2012–2019** *Electron Microscopy.* Ilona Müllerová, supported by Competence Centres of TACR

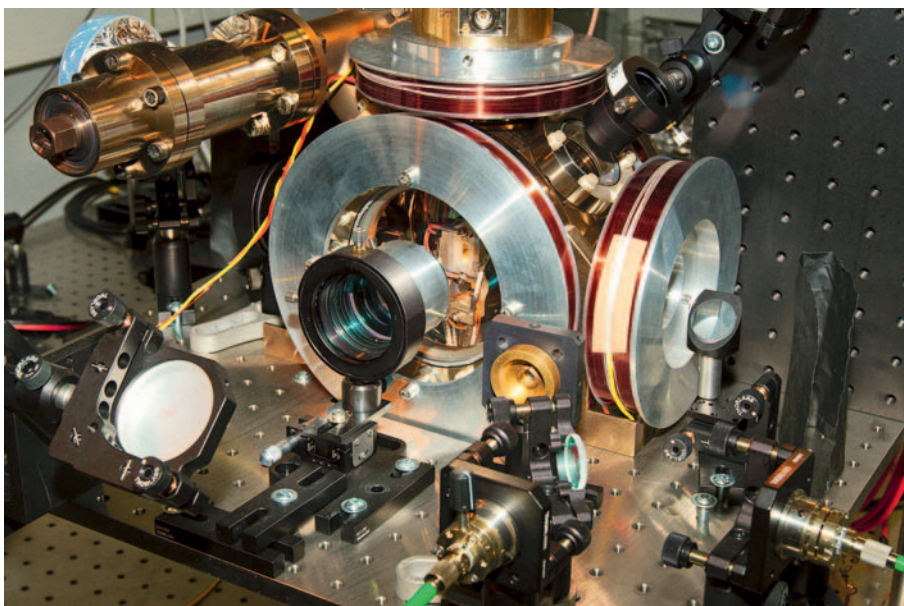


Ultra-fast ripples (UFR) show oscillation above 1000 Hz. UFRs occur only in the pathological region that is the origin of epileptic seizure.

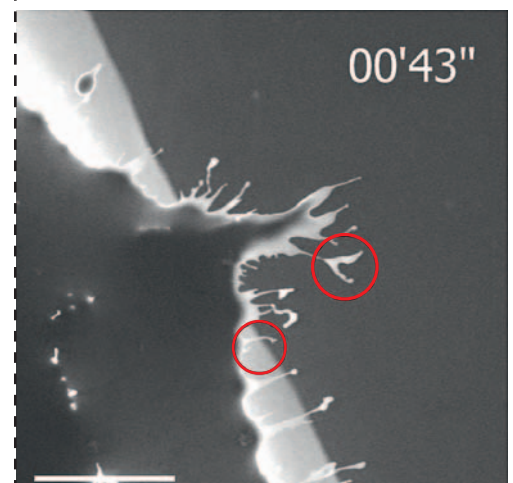
RECENT IMPORTANT ACHIEVEMENTS

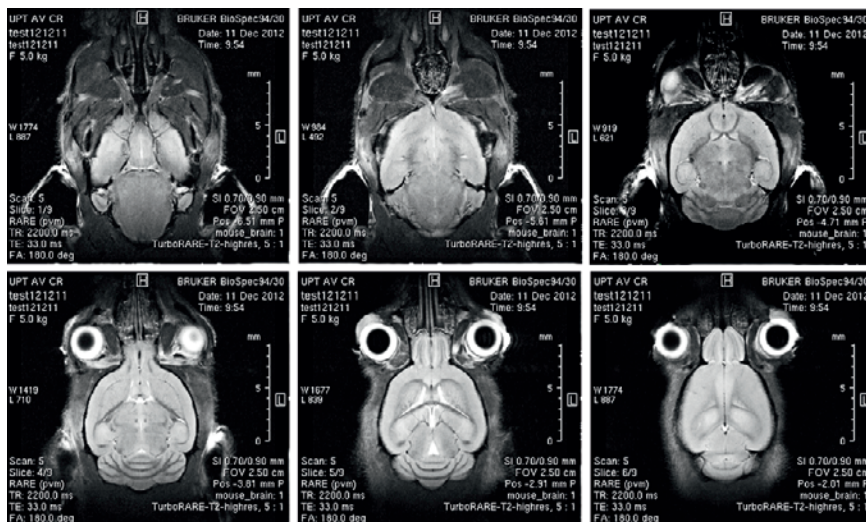
- 2018** Non-classicity of light emitted from a large number of atoms that were trapped in vacuum and laser cooled to the absolute zero has been demonstrated. The discovery is a key step towards scalable secure quantum communications. (O. Číp)

Experimental arrangement of the ion trap for Calcium ions oriented to development of ultrastable laser optical frequency standard.



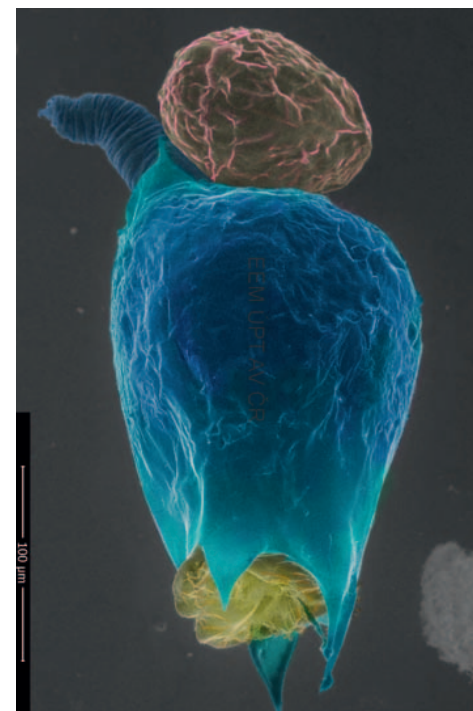
Formation of brine “fingers” during slow evaporation of water from the frost flower. The individual fingers bending and flapping around are highlighted in circles; Imaged with the Environmental Scanning Electron Microscopy (ESEM) AQUASEM II.





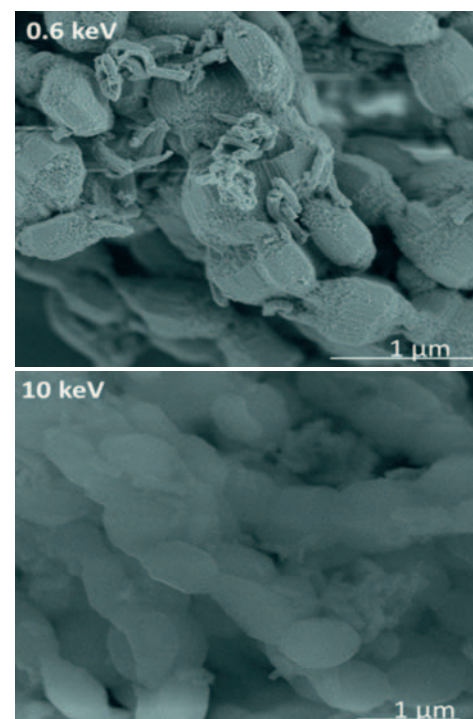
Anatomical image of a mouse brain obtained by magnetic resonance imaging.

- 2018** Three-dimensional holographic optical manipulation through a high-numerical-aperture soft-glass multimode fibre (T. Čížmár)
- 2018** A comprehensive methodology covering automatic patient identification for cardiac resynchronization therapy (P. Jurák)
- 2018** Demonstration of mechanical effect of optical spin force on a vacuum levitating microobject (O. Brzobohatý)
- 2017** Demonstration of ultra-high frequency oscillations in the brain helping precise location of the epileptic foci (P. Jurák)
- 2017** Demonstration of novel transport of many microobjects by two-dimensional optical „ratchet“ (P. Zemánek)
- 2017** Proof that the „frost flowers“ don't contribute to damage to Earth's ozone layer by the formation of aerosols (V. Neděla)
- 2017** Demonstration of fast and precise methodology that employs the machine learning algorithms to identify 277 bacterial *Staphylococcus* strains by Raman microspectroscopy (O. Samek)
- 2017** Developed technology for manufacturing diffractive optical variable imaging device (DOVID) based on phyllotactic spiral arrangements (V. Kolařík)
- 2017** Experimental verification of the theoretical model for heat transfer by the near field affected by the superconducting transition (A. Srnka)
- 2016** Successful test of national photonic network for the transmission of signals ultra-precise atomic optical clocks (O. Číp)
- 2016** SignalPlant – an open software platform for methodological solution for medical signal analysis (F. Plešinger)
- 2016** NMRScopeB for jMRUI v. 6.0 – a substantially expanded version of the simulator of quantum-mechanical behavior of coupled and relaxing systems of nuclear spins (Z. Starčuk)
- 2016** Prototype and clinical tests of a device for whole-body impedance monitoring of blood distribution and pressure wave spreading (P. Jurák)
- 2015** Demonstration of high contrast images of single layer and overlapped flakes of graphene using ultralow energy electron microscopy (L. Frank)
- 2015** Experimental trapping and laser cooling of calcium ions (O. Číp)
- 2015** Demonstration of new methods for morphological study of biopolymers and observation of sensitive biological samples in their native state using high pressure conditions of Environmental Scanning Electron Microscopy (V. Neděla)
- 2015** Developed and tested new optical fiber-based sensor for detection of shape-deformations of nuclear power plant containment (B. Mikel)
- 2014** Demonstration of extreme sensitivity of very low energy electron microscopy to image nanostructured catalyzers or nanocomposite carriers of catalyzers (E. Mikmeková)



The world's first image of *Brachionus calyciflorus* observed using low temperature method for ESEM and a new ionisation detector of secondary electrons. The image was colorized additionally.

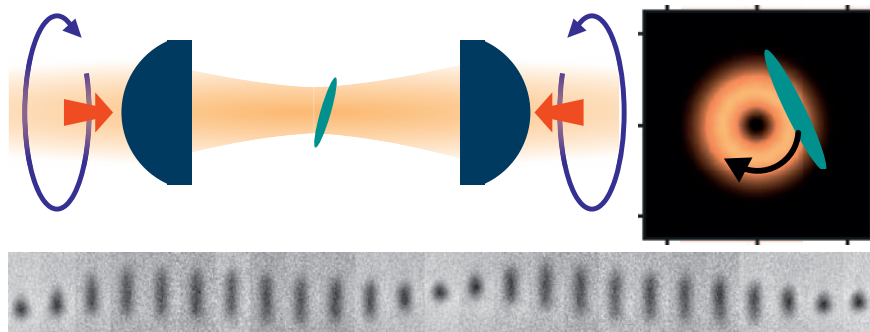
Structure of a mesoporous silica-based nanocomposite as a carrier of catalytic gold nanoparticles, imaged by means of our method of low energy electrons (top) and with a standard scanning electron microscope (bottom image).



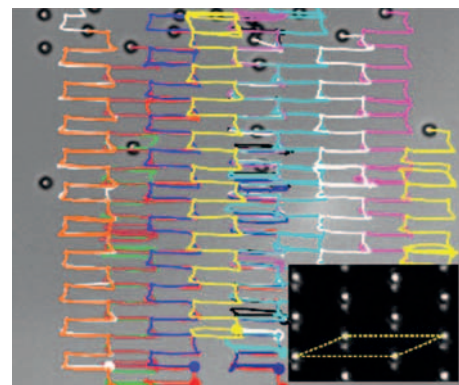
- 2014** A significant advance in electron beam based lithographic operations resulted in phase masks for sensors, dimensional standards, atypical gratings and diffraction patterns, structural colour of metallic surface, document security elements (V. Kolařík)
- 2014** Developed software and new methods of MR spectra processing provided credible quantitative local information about blood microcirculation in tissues, about changes of water relaxation and metabolic anomalies aim to support tumour research, therapy development and clinical diagnostics (Z. Starčuk)
- 2014** Objective lens of transmission electron microscope was optimized by an original method providing calculation of all types of parasitic aberrations of electron optical systems (T. Radlička)
- 2013** Experimental demonstration of optical tractor beam and its applications in optical sorting and binding (P. Zemánek)
- 2013** Observation of anomalous heat transport against temperature drop in a two-phase liquid-vapor system of cryogenic helium (A. Srnka)

RECENT HIGH-IMPACT OUTPUTS

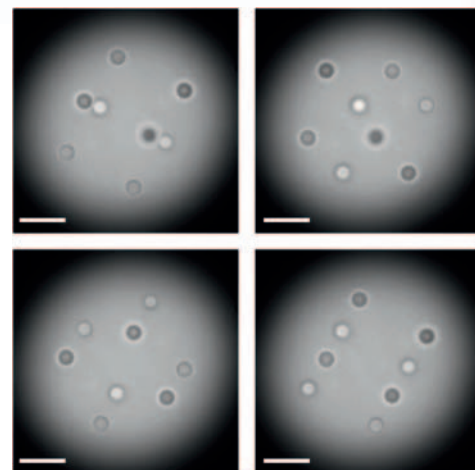
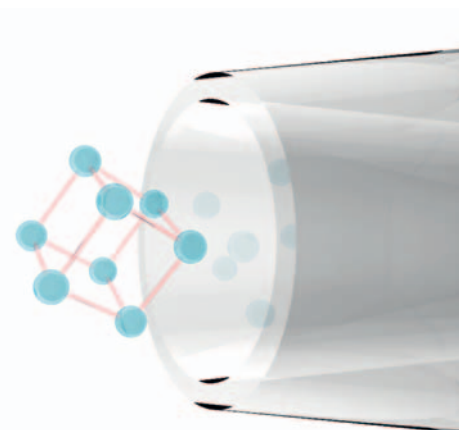
- I. Leite, S. Turtaev, X. Jiang, M. Šiler, A. Cuschieri, P. Russell, T. Čižmár: *Three-dimensional holographic optical manipulation through a high-numerical-aperture soft-glass multimode fibre*. *Nature Photonics* **12**, 33-39, 2018
- V. Svak, O. Brzobohatý, M. Šiler, P. Jákl, J. Kaňka, P. Zemánek, S. H. Simpson: *Transverse spin forces and non-equilibrium particle dynamics in a circularly polarized vacuum optical trap*. *Nature Communications* **9**, 5453, 2018
- S. Turtaev, I. Leite, T. Altwegg-Boussac, J. Pakan, N. Rochefort, T. Čižmár: *High-fidelity Multimode Fibre-based Endoscopy for Deep Brain in vivo Imaging*. *Light: Science & Applications* **7**, 92, 2018
- J. Damková, L. Chvátal, J. Ježek, J. Oulehla, O. Brzobohatý, P. Zemánek: *Enhancement of the 'tractor-beam' pulling force on an optically bound structure*. *Light: Science & Applications* **7**, 17135, 2018
- M. G. Donato, O. Brzobohatý, S. H. Simpson, A. Irrera, A. A. Leonardi, M. J. Lo Faro, V. Svak, O. M. Maragò, P. Zemánek: *Optical trapping, optical binding, and rotational dynamics of silicon nanowires in counter-propagating beams*. *Nano Letters* **19**, 342-352, 2019
- D. Boonzajer Flaes, J. Stopka, S. Turtaev, J. De Boer, T. Tyc, T. Čižmár: *Robustness of light-transport processes to bending deformations in graded-index multimode waveguides*. *Physical Review Letters* **120**, 233901, 2018
- M. Šiler, L. Ornigotti, O. Brzobohatý, P. Jákl, A. Ryabov, V. Holubec, P. Zemánek, R. Filip: *Diffusing up the hill: Dynamics and equipartition in highly unstable systems*. *Physical Review Letters* **121**, 230601, 2018
- P. Obšil, L. Lachman, M.-T. Pham, A. Lešundák, V. Hucl, M. Čížek, J. Hrabina, O. Číp, L. Slodička, R. Filip: *Nonclassical light from large ensembles of trapped ions*. *Physical Review Letters* **120**, 253602, 2018
- S.H. Simpson, P. Zemánek, O.M. Marago, P.H. Jones, S. Hanna: *Optical binding of nanowires*. *Nano Letters* **17**, 3485-3492, 2017



Silicon nanowires spinning and orbiting in circularly polarized optical vortices.



Upward motion of particles (colored trajectories) induced by periodic horizontal motion of asymmetric potential wells (bright spots in the inset) forming the two-dimensional optical ratchet.



Schematic view of eight microparticles optically trapped near the tip of the optical fiber (top). Eight particles as above forming a rotating 3D cube (bottom). Scale bar 10 micrometers.

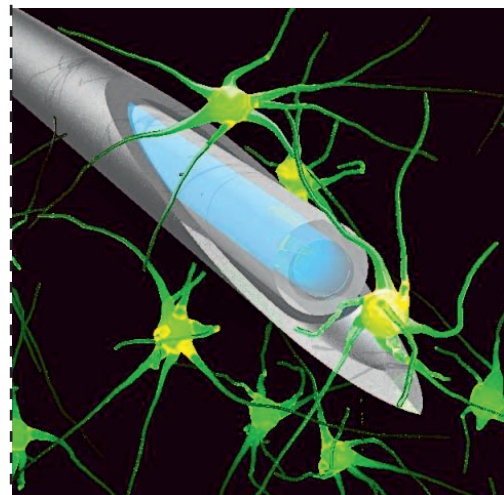
- A.V. Arzola, M. Villasante-Barahona, K. Volke-Sepulveda, P. Jákl, P. Zemánek: *Omnidirectional transport in fully reconfigurable two dimensional optical ratchets*. *Physical Review Letters* **118**, 138002, 2017
- M. Brázdil, M. Pail, J. Halánek, F. Plešinger, J. Cimbálník, R. Roman, P. Klimeš, P. Daniel, J. Chrastina, E. Brichtová, I. Rektor, G.A. Worrell, P. Jurák: *Very high-frequency oscillations: Novel biomarkers of the epileptogenic zone*. *Annals of Neurology* **82**, 299-310, 2017
- M. Antognozzi, C.R. Bermingham, R.L. Harniman, S.H. Simpson, J. Senior, I.R. Hayward, H. Hoerber, M.R. Dennis, A.Y. Bekshaev, K.Y. Bliokh, F. Nori: *Direct measurements of the extraordinary optical momentum and transverse spin-dependent force using a nano-cantilever*. *Nature Physics* **12**, 731, 2016
- J. Tuček, Z. Sofer, D. Bouša, M. Pumera, K. Holá, A. Malá, K. Poláková, M. Havrdová, K. Čépe, O. Tomanec, R. Zbořil: *Air-stable superparamagnetic metal nanoparticles entrapped in graphene oxide matrix*. *Nature Communications* **7**, 12879, 2016
- I. Rektor, I. Doležalová, J. Chrastina, P. Jurák, J. Halánek, M. Baláž, M. Brázdil: *High-frequency oscillations in the human anterior nucleus of the thalamus*. *Brain Stimulation* **9**, 629-631, 2016
- O. Brzobohatý, M. Šiler, J. Trojek, L. Chvátal, V. Karásek, A. Paták, Z. Pokorná, F. Mika, P. Zemánek: *Three-dimensional optical trapping of a plasmonic nanoparticle using low numerical aperture optical tweezers*. *Scientific Reports* **5**, 08106, 2015
- X. Zou, X. Huang, A. Goswami, R. Silva, B.R. Sathe, E. Mikmeková, T. Asefa: *Cobalt-embedded nitrogen-rich carbon nanotubes efficiently catalyze hydrogen evolution reaction at all pH values*. *Angewandte Chemie - International Edition* **17**, 4372-4376, 2014
- O. Brzobohatý, V. Karásek, M. Šiler, L. Chvátal, T. Čižmár, P. Zemánek: *Experimental demonstration of optical transport, sorting and self-arrangement using a tractor beam*. *Nature Photonics* **7**, 123-127, 2013
- P. Urban, D. Schmoranz, P. Hanzelka, K.R. Sreenivasan, L. Skrbek: *Anomalous heat transport and condensation in convection of cryogenic helium*. *Proceedings of the National Academy of Sciences of the United States of America* **110**, 8036-8039, 2013

RECENT PATENTS

- M. Horáček, V. Kolařík. *Optically variable imaging device and method of its preparation*; ISI CAS, v. v. i., 2017. Patent number: CZ 306956 B6
- V. Vondra, P. Jurák, J. Halánek, I. Višćor. *Device for blood flow property measurement and method of its connection*; ISI CAS, v. v. i. 2015. Patent number: US9167984
- J. Halánek, P. Jurák. *Method of ventricular repolarization analysis*; ISI CAS, v. v. i., 2013. Patent number: US8600485
- J. Halánek, P. Jurák. *Method of ventricular repolarization analysis*; ISI CAS, v. v. i., 2012. Patent number: EP2155055

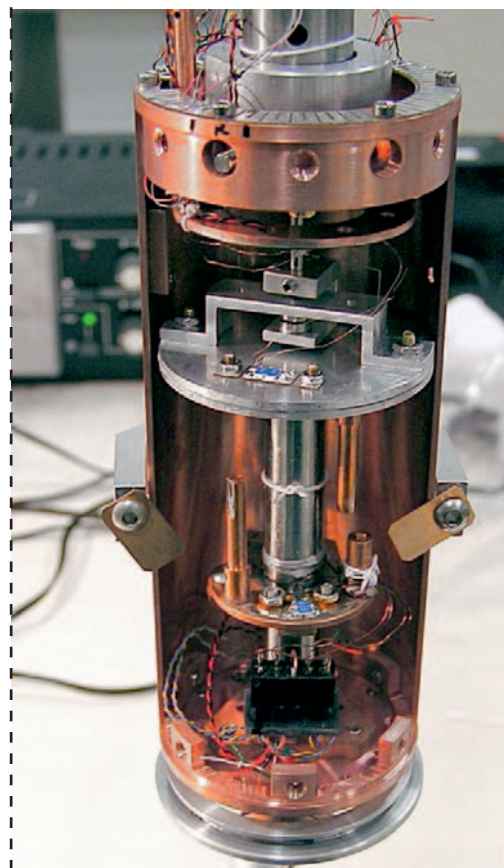
MASTERED TECHNOLOGIES

- Deposition of optical thin films by electron beam evaporation (P. Pokorný)
- Deposition of systems of thin films for extreme ultraviolet and RTG optical components by magnetron sputtering (T. Fořt)
- Manufacturing of nanostructures by electron beam writers or reactive ion etching (V. Kolařík, M. Šerý)
- Soft-lithography for microfluidic chips (J. Ježek)
- Two-photon polymerization (P. Jákl)

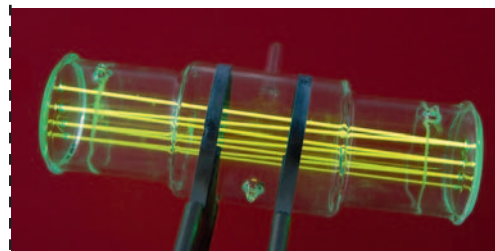


An artist's impression of endoscopic imaging of neurons in the brain using an optical fiber inserted in a hypodermic needle.

Our unique experimental system measuring thermal emissivity of samples kept at temperatures ranging from room to cryogenic.



- Liquefaction of helium (A. Srnka)
- Electron-beam welding of parts from different metals (M. Zobač)
- Laser beam cutting and welding (L. Mrňa)
- Electron microscopy and microanalysis (F. Mika)
- Cuvettes filled with ultrapure gases for precise spectroscopy and metrology (J. Lazar)
- MR tomographic imaging (Z. Starčuk)
- High-voltage electronics (M. Zobač)
- Measurement of thermal radiative properties of materials in the range from 10 K to 300 K for cryogenic and space applications (A. Srnka)
- On-demand design and construction of scientific instruments or their parts
- Optical micromanipulation with various types of microobjects or microorganisms. (O. Brzobohatý, O. Samek)
- Contactless characterization of living microorganisms by Raman microspectroscopy (O. Samek)
- Imaging through multimode optical fibers (T. Čížmár)



A cuvette filled with iodine gas equipped with internal mirrors designed for applications in ultraprecise nanometrology. Fluorescent yellow paths visualize multiple passages of a laser beam.

HISTORY OF ISI

- 2009** Applied Laboratories of ISI (ALISI) established
- 2007** ISI transformed to Public Research Body (v. v. i.)
- 1993** Academy of Sciences of the Czech Republic established as the Czech descendant of former Czechoslovak Academy of Sciences
- 1961–1990** Armin Delong as a director of ISI
- 1960** Laboratory of Electron Optics and Laboratory of Industrial Electronics joined ISI in new building
- 1957** Development Workshop of the Czechoslovak Academy of Sciences (DWCAS) renamed to Institute of Scientific Instruments (ISI)
- 1953** Establishment of DWCAS

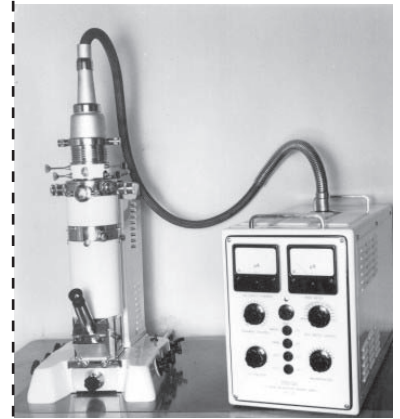
Entrance to Applied Laboratories of ISI (ALISI).

REMARKABLE ACHIEVEMENTS IN THE PAST

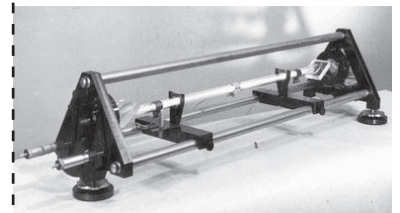
- 2012** Identification of the local crystallographic orientation from the reflectance of very slow electrons
- 2012** Novel methods and system for contactless calibration of gauge blocks
- 2011** Experimental determination of heat transfer efficiency in natural turbulent convection at high Rayleigh numbers in cold helium gas
- 2009** Novel sample nanopositioning system for nanometrology AFM using interferometric measurement in all six degrees of freedom (axial motions and angle deviations)
- 2009** Original approach for the calculation of aberration coefficients using the results of accurate electron ray tracing
- 2008** Novel laser nanocomparator for the calibration of length sensors, in cooperation with the Mesing company and Czech Metrology Institute
- 2007** Prototype of an original electron beam welding machine for Focus GmbH
- 2005** The world's first concept of optical conveyor belt was presented and demonstrated in cooperation with University of St. Andrews (UK)
- 2004** Development of a new experimental apparatus for the measurement of low temperature radiative properties of materials used in cryogenics
- 2004** Development of various nanocomposite coatings used as hard solid lubricants in cooperation with Masaryk University, Aarhus university Denmark, University of West Bohemia Pilsen, Czech Technical University in Prague, Brno University of Technology, Euroconsult and the Institute of Electrical Engineering of the Slovak Academy of Sciences
- 2004** New environmental scanning electron microscope AQUASEM II



- 2004** New method of length measurement using optical cavity with sub-nanometer resolution 2000 – New type of electron microscope using very slow electrons was demonstrated
- 1990** The first Czechoslovak ESEM, AQUASEM I
- 1987** The first Czechoslovak ultra-low loss cryostat for NMR magnets
- 1987** Original setup of iodine-stabilized HeNe laser for metrological purposes
- 1985** The first electron beam lithograph in the Eastern Block developed at ISI and commercialized by the TESLA company
- 1978** The first Czechoslovak Fourier NMR spectrometer
- 1976** Scanning electron microscope with a cold field emission gun
- 1972** The first Czechoslovak superconducting magnet for NMR
- 1971** Gold medal at the International Brno Fair for laser interferometric system LA3000 developed at ISI and produced by the Metra Blansko company
- 1966** NMR spectrometers commercially produced by the TESLA company
- 1965** The first Czechoslovak ruby laser
- 1963** The first Czechoslovak HeNe laser
- 1960** The first Czechoslovak nuclear magnetic resonance (NMR) spectrometer (30 MHz)
- 1959** TEM with resolution below 1 nm
- 1958** Gold medal at the Brussels World's Fair EXPO58 for the table-top TEM
- 1954** The world's first table-top TEM developed at Laboratory of Electron Optics (LEO)
- 1951** Tesla BS 241 – the first Czechoslovak commercial TEM developed at LEO and TESLA company
- 1950** The first Czechoslovak transmission electron microscope (TEM) developed at LEO



The first table-top transmission electron microscope developed at the predecessor of ISI in 1954 and produced by TESLA Brno.



The first HeNe laser operating in Czechoslovakia at the wavelength 633 nm.

ISI in 60 years and 4 seasons

Diffraction optically variable image device based on a patented approach taking advantage of spiral cross grating arrangements (quasiperiodic phyllotaxy model). The device is captured at four different lighting conditions demonstrating its outstanding potential of image variability.

