Group of Magnetic Resonance

Department of Magnetic Resonance and Cryogenics

Institute of Scientific Instruments AS CR, v.v.i.

THEMATIC RESEARCH FOCUS

Research area

Nuclear magnetic resonance imaging
Nuclear magnetic resonance spectroscopy in vivo
MR for preclinical research with small laboratory animal models
MR imaging for medical diagnostics
MR for material research and development

Excellence

MR spectroscopy in vivo – spin system simulation, pulse sequence development.
MR measurement of perfusion – pharmacokinetic modeling.

Mission

1. Research into the biological, chemical and physical background of modern MR techniques, incl. MR in ultra-high fields, fast steady-state techniques, computer simulation of spin systems as a tool for method design and quantitation.
2. Development of measurement techniques and advanced physical and physiological data modeling, incl. uncertainty assessment for robust quantitative MR imaging of relaxation, diffusion and perfusion, MR spectroscopy and spectroscopic imaging, and their application to study dynamics. The focus is on in vivo applications in preclinical imaging and human diagnostics, particularly on metabolite quantitation and pharmacokinetic modeling of perfusion.
3. Development of applications of MR techniques for specific biomedical research and medical diagnostics of neurologic, cerebrovascular, oncologic diseases, incl. application of exogeneous contrast nanoparticles, and data mining from multiparametric MR images.
4. Support of biomedical research by providing complex MR services with laboratory animals.
5. MR measurements for plant biology and industrial material research and development.

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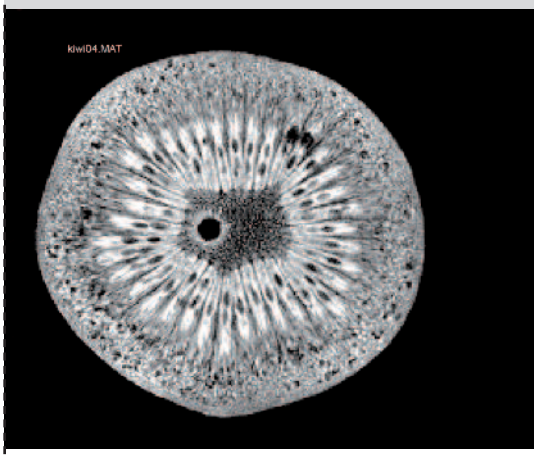


Kiwi fruit cross-section, MRI at 4.7 T

Preclinical 9.4T MR scanner equipped for mouse/rat imaging

DEVELOPED TECHNOLOGIES

Content of research

1a. Behaviour of coherence in coupled spin systems in fast multipulse excitation and its computer simulation

1b. Computer simulation of coupled spin system as a tool for pulse sequence design, development of MR spectroscopic data analysis and metabolite quantitation, and for education. The goal is to provide a comprehensive and practical analytical tool covering multiple relevant phenomena (chemical shift, spin-spin coupling, relaxation, magnetization transfer, chemical exchange, field inhomogeneity, motion)

2a. Pharmacokinetic modeling in MR imaging of perfusion – model development, algorithm implementation, experimental verification, application

2b. Metabolite quantitation in MR single voxel spectroscopy and spectroscopic imaging – model development, algorithm implementation, experimental verification, application

2c. Assessment of model parameter uncertainty, its reduction by MR measurement optimization

3a. Multiparametric MR including relaxometry, diffusion tensor imaging and fibre tractography, perfusion measurement, functional MR imaging, spectroscopy – optimized protocols for biomedical research and medical diagnostics, research into efficient data fusion, presentation, and classification

3b. Research into experiment parameters and biological, chemical and physical factors affecting MR measurements in animal models

4a. Development of standard operation procedures for animal MR measurements

5a. Water transport – diffusion and perfusion in plants

5b. MR characterization of gels and porous materials

Main capabilities

Core competence

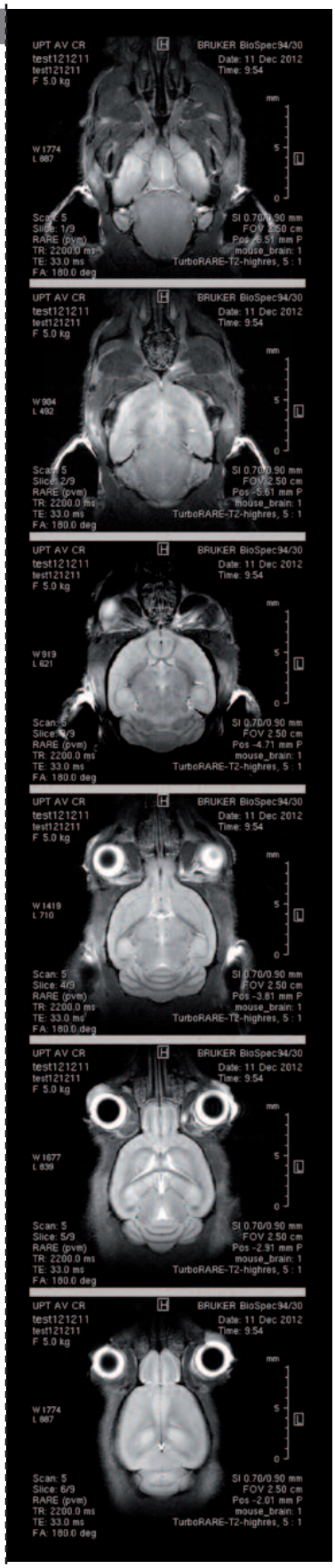
– Pulse sequence design and analysis by computer simulation of spin system evolution
– MR data analysis for the measurement of relaxation, diffusion, perfusion, spectroscopy
– Verification of measurement protocols and analytics by phantom studies
– Development of customized MR protocols

Application areas

– Phenotyping of murine animal models by multiparametric MR examination
– Research into etiology and pathophysiology of diseases in animal models
– Development of therapeutical procedures and drugs: efficiency, targeting, toxicity
– Animal model based development of diagnostics for medical use
– Testing nanoparticle carriers for targeted markers and drugs
– Plant development, genomics
– Study of properties of technical gels
– Characterization of porous materials

Fields of research results application

– Life-sciences (animal model based research into neurodegeneration, psychiatric, cerebrovascular, cardiovascular, oncologic diseases, drug targeting tests, nanoparticle deposition for toxicity assessment)
– Electrotechnics and power storage (characterization of specific gels)
– Construction industry (characterization of specific gels – concrete, and porous materials – wood, foams)
– Food and drug industry (structure, water/fat/air content and its dynamics, deterioration processes)
– Magnetic resonance education for university students and MR professionals (virtual scanner)



Anatomical T2 weighted MR images of a mouse brain at 9.4 T

KEY RESEARCH EQUIPMENT

- MR scanner 9.4T/30cm Bruker BioSpec Avance III 94/30 (^{1}H 400 MHz), 300 mT/m gradients, 660 mT/m gradient insert for microimaging, multinuclear (^{31}P, ^{13}C, ^{19}F, ^{129}Xe), RF coils for mouse/rat/rabbit measurement, 2 transmit, 4 receive channels
- isoflurane anesthesia, vital function monitor SAII 1030, artificial ventilation, animal bed heating, minisurgery room
- animal facility for 200 mice and 100 rats with overpressure and EU14 filtration, animals in individually ventilated cages, hygienic loop, autoclave, UV sterilization chamber, laminar flow boxes
- wet lab with fume chamber, deep freezer (-80 °C), cadaver freezer
- MR scanner 4.7T/20cm with magnet Magnex Sci. Ltd., console MR Solutions MR6000, 1kW RF amplifier CPCAmps 5T1000M, gradients 180 mT/m, Gz insert 1000 mT/m

ACHIEVEMENTS

Ultra-short echo-time spectroscopic techniques exhibiting particularly robust water suppression and low contamination have become a worldwide standard and make it possible to reliably determine up to 20 metabolites in brain MR spectra.

- Tkáč, I.; Starčuk, Z.; Choi, I.–Y.; Gruetter, R.; *In Vivo 1H NMR Spectroscopy of Rat Brain at 1 ms Echo Time.* Magnetic Resonance in Medicine 41, (1999), p. 649–656.
- Mlynárik, V.; Gruber, S.; Starčuk, Z.; Starčuk Jr., Z.; Moser, E.; *Very Short Echo Time Proton MR Spectroscopy of Human Brain With a Standard Transmit/Receive Surface Coil.* Magnetic Resonance in Medicine 44, (2000), p. 964–967.
- Starčuk, Z.; Mlynárik, V.; Roden, M.; Horký, J.; Moser, E.; *Low-Power Water Suppression by Hyperbolic Secant Pulses with Controlled Offsets and Delays (WASHCODE).* Journal of Magnetic Resonance 152, (2001), p. 168–178. DOI: 10.1006/jmre.2001.2392.

A simulator of coupled spin systems undergoing relaxation and spatially--frequentially-inhomogeneous excitation (NMRScopeB) has been developed and integrated into jMRUI software, used at over 2000 institutions worldwide.

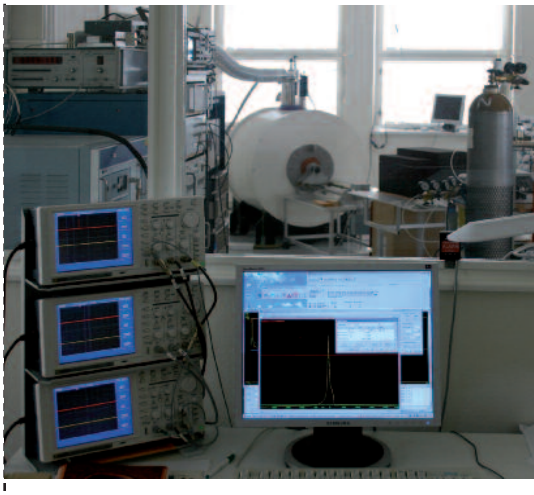
- Stefan, D.; Di Cesare, F.; Andrasescu, A.; Popa, E.; Lazariev, A.; Vescovo, E.; Strbak, O.; Williams, S.; Starčuk, Z.; Cabanas, M.; van Ormondt, D.; Graveron-Demilly, D.; *Quantitation of magnetic resonance spectroscopy signals: the jMRUI software package.* Meas. Sci. Technol. 20, (2009), 104035, 9p. DOI:10.1088/0957-0233/20/10/104035.

Techniques for accurate measurement of material properties (relaxation, magnetic susceptibility) have been developed and applied in practical studies.

- Starčuková, J.; Starčuk Jr., Z.; Hubálková, H.; Linetskiy, I.; *Magnetic susceptibility and electrical conductivity of metallic dental materials and their impact on MR imaging artifacts.* Dental materials 24, (2008), p. 715–723. DOI: 10.1016/j.dental.2007.07.002.
- Kořínek, R.; Vondrák, J.; Bartušek, K.; Sedlaříková, M.; *Experimental investigations of relaxation times of gel electrolytes during polymerization by MR methods.* J Solid State Electrochem, (2012). DOI 10.1007/s10008-012-1715-6.

Models and algorithms have been developed for pharmacokinetic analysis of perfusion based on MR measurement of contrast agent bolus dynamics in the animal and human body. Perfusion is an important process in cancer, brain injuries, neurodegenerative diseases and drug targeting – this development aids the diagnostics, therapy development, and basic research of pathophysiology.

- Taxt, T.; Jiřík, R.; Rygh C. B. Grüner, R.; Bartoš, M.; Andersen, E.; Curry F.-R.; Reed, R. K.; *Single-Channel Blind Estimation of Arterial Input Function and Tissue Impulse Response in DCE-MRI.* IEEE Transactions on Biomedical Engineering 59, 4, (2012), p. 1012–1021. DOI 10.1109/TBME.2011.2182195.



4.7 T MR laboratory

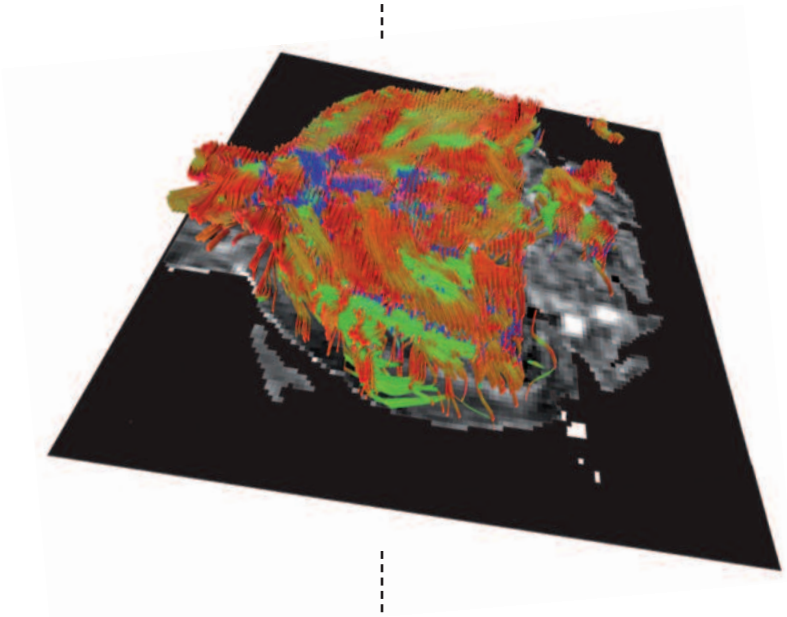
MAIN COLLABORATING PARTNERS

Collaboration with academic partners

Katholieke Universiteit Leuven (Leuven, BE)
Ecole Polytechnique Fédérale de Lausanne (Lausanne, CH)
University of Manchester (Manchester, UK)
Max Planck Institute for Human Cognitive and Brain Sciences (Leipzig, DE)
Radboud University Nijmegen Medical Centre (Nijmegen, NL)
Universitat Autonoma de Barcelona (Barcelona, ES)
University of Bern (Bern, CH)
Université Claude Bernard Lyon 1 (Lyon, FR)
Delft University of Technology (Delft, NL)
Instytut Fizyky Jadrowej PAN (Kraków, PL)
Masarykova univerzita (Brno, CZ)
Vysoké učení technické (Brno, CZ)
Fakultní nemocnice u sv. Anny – ICRC (Brno, CZ)
Výzkumný ústav veterinárního lékařství (Brno, CZ)

Collaboration with companies

Philips Healthcare (Nijmegen, NL)
Siemens Healthcare (Erlangen, DE)
Bruker Biospin (Ettlingen, DE)
AlterSystems (Lyon, FR)
icoMetrix (Leuven, BE)



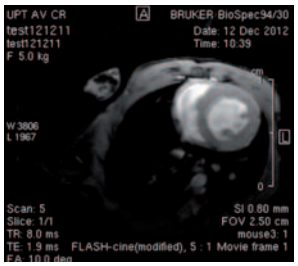
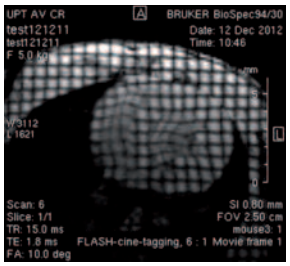
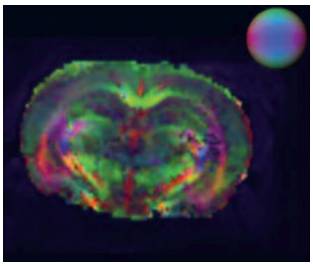
Neuronal fiber tracking based on diffusion tensor imaging in mouse brain

EXPECTATIONS

Offers

– Development of MR measurement protocols for specific applications
– Development of MR data analysis methods (measurement of relaxation, diffusion, perfusion, spectroscopy)
– Multiparametric testing of animal models by MR methods
– Multiparametric testing of disease markers, drugs, therapeutic procedures in animal models
– Characterization of gels or porous materials
– MR imaging of small diamagnetic objects, MR data analysis
– Nanoparticles in animals

Requirements

– Biomedical research and development using small laboratory animals (mouse, rat) by methods of magnetic resonance, behavioural testing possible upon request, complementary imaging modalities welcome.

Mouse cardiac real time MR imaging without and with tagging, angiography, diffusion tensor imaging (left to right)