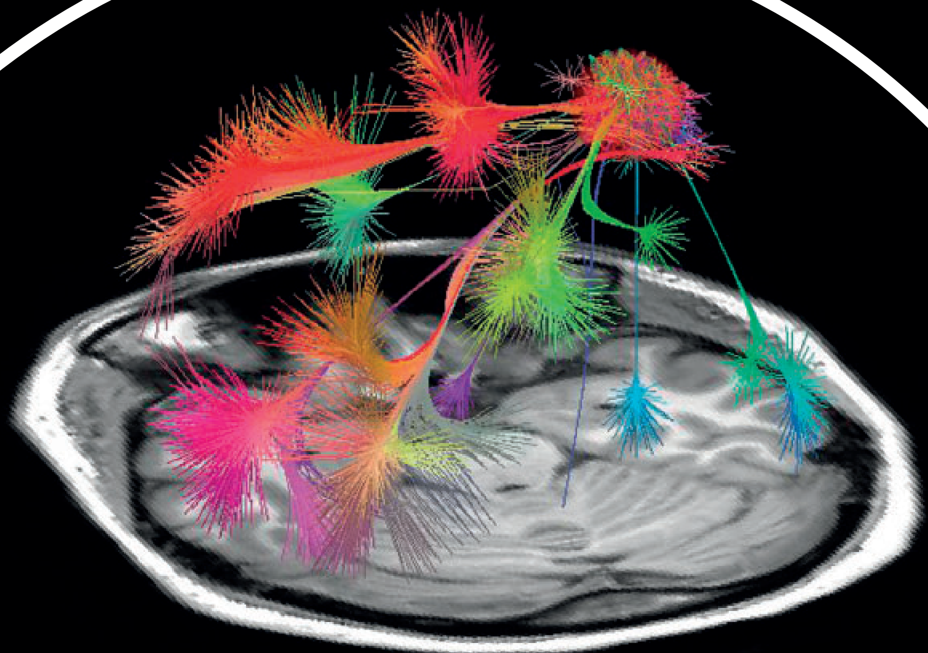
ESMRMB

European Society for Magnetic Resonance in Medicine and Biology



Lectures on MR 2014

Educational courses, exercises, and practical demonstrations on MR physics and engineering

Resting state fMRI - basic concepts, methods & applications
May 19–21, Cambridge/UK

Parallel Imaging: Basic and advanced transmission and reception concepts
June 12-14, Würzburg/DE

RF coils: Design, build and characterise your own
June 17-19, Berlin/DE

fMRI and optogenetics: Probing networks in the animal brain NEW!
June 25-27, Münster/DE

Create your own echo: How to generate, calculate and manipulate echoes
September 17-19, Munich/DE

Diffusion weighted MR spectroscopy: How to acquire, process, analyse and model metabolite diffusion weighted data NEW!
September 22-24, Leiden/NL

Susceptibility weighted imaging and quantitative mapping NEW!
November 17-19, Graz/AT

In vivo MRI and MRS with X-nuclei NEW!
November 25-26, Freiburg/DE

Acquisition strategies for hyperpolarised spin systems: Spectral, spatial and temporal
December 9-11, Munich/DE

10th Anniversary

www.esmrmb.org

ESMRMB 2015
OCTOBER 1–3
EDINBURGH/UK

MARK YOUR CALENDAR!

32ND ANNUAL SCIENTIFIC MEETING

The European Forum for MR research and clinical practice
www.esmrmb.org

ESMRMB
European Society for Magnetic Resonance in Medicine and Biology

Content

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Cover Image: Courtesy of Gabi Lohmann, MPI for Biological Cybernetics and University of Tübingen, Germany
Scientific images kindly provided by the organisation committee 2014.

General Information

Course Information

- All courses are held in English language.
- The duration of the course is 2 to 3 days.
- The detailed programme of each course and the exact time schedule are available at the ESMRMB website.
- About 40% of the total teaching time is used for repetitions, exercises, and practical demonstrations to practice and intensify the learning experience.
- A maximum of 50 places per course are available (except for the RF coil design course in Berlin/DE which is limited to 25). Early registration is recommended.
- If less than 20 participants register, the ESMRMB reserves the right to cancel a course at the latest 4 weeks prior to its beginning.
- The ESMRMB ensures the evaluation and certification of all courses, and guarantees didactically and scientifically experienced teachers.

Accreditation

The **Lectures on Magnetic Resonance** programme is accredited by the **European Federation of Organisations for Medical Physics (EFOMP).** A certificate of attendance will be available online for the participants of the entire course.

Sponsorship Acknowledgement

The course on **fMRI and optogenetics: Probing networks in the animal brain** (Münster/DE) is kindly supported by Bruker.

BRUKER

Exclusive sponsor

The course on **Parallel Imaging: Basic and advanced transmission and reception concepts** (Würzburg/DE) is exclusively sponsored by Siemens.

SIEMENS

10th Anniversary

Lectures on MR celebrates its 10th anniversary!

In 2014 the Lectures on MR Programme celebrates its 10th anniversary. Since its launch in 2004, 54 courses were held in 16 different countries and 33 cities. So far, more than 1700 experts joined the Lectures on MR programme, which has proven its high quality standard throughout the last decade. We would be delighted to welcome you to our Lectures on MR programme in its anniversary year!

Goals of the Courses

With the **Lectures on Magnetic Resonance** the ESMRMB continues to offer new teaching courses that are especially designed to provide the physical fundamentals of MR imaging, diffusion, perfusion, spectroscopy and RF engineering, as well as aspects of applications of these techniques in clinical and biochemical research and development. The ESMRMB and its Education and Workshop Committee is convinced that there is a strong need and request to provide these kind of courses that are dedicated towards the needs of MR physicists and other basic scientists working in a clinical or research environment.

The course on **Resting state fMRI - basic concepts, methods & applications** focuses on methodology and applications of this rapidly growing field. An overview will be provided on the major analysis strategies, applications, including those in clinical populations, and special emphasis will be put on the importance of physiological and other confounding factors, and the impact of different acquisition strategies. The course will be complemented by ample hands-on training, which will provide participants a good overview of the major software suites used by the field to analyse resting state data.

The course on **Resting state fMRI** will provide you with

- Insights into the sources of correlated resting state activity
- Knowledge on the most important analysis strategies
- Methods to control physiological noise contributions
- Techniques to quantify local resting state behaviour
- Proficiency to perform network analysis
- Deeper understanding of the meaning of abnormal resting states
- Practical guidelines for resting state acquisitions
- An overview on critical aspects and limitations
- A perspective on future directions in this field of research

The course on **Parallel Imaging** is designed to provide a firm conceptual and practical foundation. Attendees will be brought up to date with established techniques and will develop an appreciation of emerging technologies and methods in multi-channel MRI. The three-day course will rely heavily on interactive tutorials using the MATLAB programming environment. Computers and licenses will be provided for the length of the course. At the end of the course attendees will understand the basic principles and practical implementation of cartesian and non-cartesian Parallel Imaging methods, spatio-temporal undersampling methods, Compressed Sensing and parallel transmit. Attendees will also appreciate the role of these methods in established and research practice and how such methods may develop and influence MRI research and practice in the future.

The course on **Parallel MRI** will focus on

- Image domain pMRI – reconstruction methods
- K-space pMRI – reconstruction methods
- Artifacts & pitfalls in Parallel Imaging
- Coils and calibration – practical implementation
- Iterative methods & non-cartesian reconstruction
- Advanced Parallel Imaging strategies
- Spatio-temporal undersampling and reconstruction
- Compressed Sensing (CS)
- Parallel transmission – theory and practice
- Future directions in multi-channel MRI

The course on **RF coils: Design, build and characterise your own** provides an overview of the basic theory of designing, constructing and testing RF coils for both animal and human scanners. Introduction into software tools for simulations of electromagnetic fields and for safety evaluation will be included. Practical sessions will cover approximately ~50% of the course, in which participants will learn to build surface coils and volume resonators of their particular interests. Characterisation of RF coils including B1-mapping, measurement of E and H fields and assessment of Parallel Imaging performance will be also part of the course. The course is designed for basic scientists and engineers but also invites clinicians, radiographers, application specialists, (under)graduate students and other MR users interested in gaining a better insight into RF coil technology.

The course on **RF coils** will enable you to

- Understand the behaviour of circuit elements at high frequency
- Understand the concepts of resonance and resonant circuits
- Design impedance matching networks
- Construct baluns and cable traps
- See the range of test equipment used in RF coil design
- Design and build a surface coil
- Understand the theory of volume resonators
- See the operation of different software packages for RF simulations
- Understand the different designs for multiple-frequency RF probes
- Design a birdcage coil
- Build your own coil

The new course on **fMRI and optogenetics: Probing networks in the animal brain** will address basic and advanced aspects of fMRI and optogenetics in rodents as well as basic aspects of neurophysiology and networks of the brain. It will provide basic knowledge about the neurophysiological basis of the fMRI signal (neurovascular coupling), and about neuronal network oscillations in health and disease. Appropriate animal handling, anaesthesia, and monitoring as well as how to maintain a stable physiological state during imaging will be explained. All key steps needed for the implementation of a combined optogenetic-fMRI approach will be introduced.

The course on **fMRI and optogenetics** will emphasise

- MRI methods to study the brain, analysis of fMRI data
- Special requirements for small animal MRI: Rodent physiology and monitoring, anaesthesia
- Basics of optogenetics: Opsins, viral delivery and cell type specificity, stimulation techniques
- Basics of neurophysiology, neurophysiological methods, optical and electric detection of neuronal activity
- Neurovascular coupling and networks of the brain
- Combination of fMRI with other readouts and stimulations: ofMRI, optical Ca^{2+}-ofMRI

The course on **Create your own echo: How to generate, calculate and manipulate echoes** offers a physically and mathematically oriented description of basic and non-basic physical properties of spins exposed to penetrating radio frequency and gradient fields. Is it possible to generate a spin echo with two 10-degree RF pulses? What is the difference between a spoiled gradient echo sequence and a balanced steady state free precession technique? How can we calculate amplitude and phase of spin echoes, stimulated echoes and steady state signals?

Attendance of the course will provide you with a fundamental knowledge of

- Handling and calculations with the Bloch equations
- Understanding of sampling trajectories in k-space
- Fourier description of magnetisation, the phase-graph
- Counting of echo paths in a multi-pulse experiment
- Behaviour of multiple spin-echo techniques at low flip angles
- Mathematical description of steady states and their resulting contrasts
- Application of Hyper Echoes to gradient echo methods
- Exotic sequences, Hyper Echoes, TRAPS

Diffusion weighted MR spectroscopy (DWS) provides unique information on intracellular microstructure and physiology. The high compartmental specificity of DWS, as well as the cell-specific nature of some of the metabolites, e.g. the neuron-specific N-acetylaspartate and glutamate, or the astrocytic myo-inositol, make DWS a powerful tool for the investigation of intracellular structure and function, and their modulation by disease, aging and other processes of interest. Obtaining meaningful, robust and reproducible

DWS data poses a series of challenges, from the pulse sequences used to generate single-voxel and spectroscopic imaging DWS data, through the processing and analysis stages, to the modelling of the results based on known compartmental geometries. Attendees will be brought to date with every aspect of DWS – the design and optimisation of DWS pulse sequences, pitfalls and major obstacles for the acquisition of high-quality, robust DWS data in brain and muscle, the ways to overcome these difficulties, post-processing and analysis approaches and useful modelling strategies for obtaining meaningful microstructural information.

The course **Diffusion weighted MR spectroscopy** will focus on

- Introduction to DWS: Why do we need it and where can it become useful?
- Single-voxel DWS: Which sequences can be used? Which sequence to actually use to answer a specific question?
- Design of optimal single-voxel DWS sequence: Minimisation of eddy current effects, signal amplitude and phase fluctuations, cross-terms with background gradients, isotropic DWS
- Diffusion-weighted MR spectroscopic imaging (DW-MRSI): The use of cardiac gating and navigators to correct phase and amplitude fluctuations, re-acquisition schemes, effective eddy current correction without separate acquisition of water data, challenges and solutions for multi-echo acquisitions
- Non-proton DWS: Challenges and possibilities in 31P-DWS
- Post-processing of DWS data: Efficient correction for signal fluctuations and eddy currents, retrospective rejection of bad data
- Analysis of DWS data: Proper quantification of DW metabolite information
- Modelling of DWS data: Incorporating simple geometries and information from additional MR sources for obtaining meaningful intracellular information
- Emerging applications in neuroscience and clinical research

Progress in **Susceptibility weighted imaging and quantitative mapping** has opened a new window into tissue composition and microstructure. The aim of this three-day course is to provide the fundamentals of this fast growing field. The course will cover the physical basics of magnetic susceptibility, susceptibility weighted pulse sequences, and reconstruction methods to produce qualitative and quantitative susceptibility maps. A special emphasis will also be put on clinical and preclinical applications. This course is dedicated to MR physicists, basic scientists, and clinicians who already have a basic background in MRI.

The course will cover

- Theory of magnetic susceptibility
- Formation of bulk susceptibility in biological tissues
- Pulse sequences and implementation issues
- Methods for phase processing and background field removal
- Strategies for solving inverse problems
- Validation of biophysical contributors to magnetic susceptibility
- Clinical and preclinical applications

The course on **In vivo MRI and MRS with X-nuclei** will provide an in-depth insight into magnetic resonance methods that acquire signals from nuclei other than the proton. The course is intended for MR researchers at an intermediate level with prior knowledge and/or experience with proton MRI or MRS. After completion of the course participants should be familiar with the possibilities and pitfalls of X-nuclear imaging and spectroscopy. Starting from a basic introduction into the differences and similarities of X-nuclear and proton MR, the course will cover different acquisition techniques for in vivo X-nuclei. Acquisition techniques and applications of all biologically relevant X-nuclei will be covered, and a brief introduction into the use of hyperpolarised nuclei will be given. The specialties of pulse sequences and RF coil hardware for X-nuclear MR will be presented, and applications for both small animal and human studies will be discussed. In the two-day course practical exercises will cover both theoretical parts on image acquisition and reconstruction as well as hand-on parts at a small animal and a whole body MR system.

The course on **In vivo MRI and MRS with X-nuclei** will focus on

- MR physics of X-nuclei
- Applications for X-nuclear MR techniques
- Ultrashort-TE sequences
- Coherence transfer techniques
- Basic and dual-tuned Tx/Rx coils
- Special coil requirements for X-nuclei
- X-nuclear techniques to study energy metabolism, cellular vitality, oxygen metabolism, ventilation and more
- Pre-clinical studies in small animals
- Clinical studies in volunteers and patients

Hyperpolarisation has opened up new applications of NMR and MRI. **Acquisition strategies for hyperpolarised substances** differ substantially from those suitable for thermally polarised samples due to the non-recoverable magnetisation. The aim of this three-day course is to provide the participants knowledge of experimental and theoretical aspects of polarisation, magnetisation use, pulse sequence design and RF hardware for in vitro and in vivo hyperpolarised MR. Different imaging strategies will be presented with emphasis on the special requirements and adaptations needed for hyperpolarisation studies. The use of specialised RF pulses will be covered as well as possibilities for accelerated acquisitions by means of Parallel Imaging and Compressed Sensing. Quantification and modelling of data are important aspects of hyperpolarisation studies and specialised methods will be described as the last part of the course. An integrated part of the course will be theoretical exercises where the participant will work in more depth and gain hands-on experience on the topics covered in the lectures. The course is aimed at post-graduate and post-doctoral MR scientists interested in learning about acquisition strategies for NMR and MRI of hyperpolarised spin systems. A solid background in MR physics is assumed. The three-day course is followed by an optional, voluntary extra day (December 12, 2014) with practical sessions at the hyperpolariser and MRI scanner.

The course on **Acquisition strategies for hyperpolarised spin systems** will focus on

- The advantages and limitations of the different hyperpolarisation methods
- The relevance of different relaxation mechanisms and their time scale
- Hardware requirements for imaging of hyperpolarised spins
- Basic imaging sequences for chemical shift imaging (CSI and EPSI)
- Advantages and limitations of non-cartesian (radial/spiral) sequences and how to exploit the sparsity of the spectral dimension
- Advantages and limitations of spin-echo and steady-state sequences
- The design of specialised RF pulses for spectral-spatial excitation
- Parallel Imaging methods for hyperpolarised molecules
- Compressed Sensing and sparse sampling strategies efficiently
- Quantification of spectral data such as intensity, integration, frequency and time domain fitting (jMRUI, LCmodel)
- Modelling of kinetic (temporal) data, explain exchange reactions and methods of solving the rate equations, and correct for relaxation and RF excitation
- The biological interpretation of rate constants and other parameters extracted from in vivo hyperpolarisation data

Educational Levels

The **Lectures on Magnetic Resonance** are dedicated to MR physicists and other basic or clinical scientists. The Lectures are certified by the **European Federation of Organisations for Medical Physics (EFOMP).**

Resting state fMRI - basic concepts, methods & applications

The intended audience should be familiar with the basic concepts of functional MRI studies, including standard analysis strategies for task-based approaches. The course therefore is suitable for PhD students and post-doctoral scientists in psychology, neuroscience or MR physics. A basic understanding of BOLD physiology, MR physics, and brain anatomy is expected. The focus on analysis strategies will provide greatest benefit for those planning or starting data acquisition or analysis, or for researchers wanting to get a good overview of the potential of this method.

Parallel Imaging: Basic and advanced transmission and reception concepts

This course is intended for MR physicists, other scientists and PhD students who already have experience in basic MR methods and knowledge of MR acquisition principles, and who wish to extend their knowledge on Parallel Imaging principles and techniques. Some knowledge of MATLAB will be advantageous. All tutorials will be based around pre-existing code prepared for this course. Attendees without any MATLAB experience should have other programming experience and be willing to work with MATLAB.

This course runs from introductory to advanced methods over the three days. At the end of these three days attendees will take with them the MATLAB code that has been provided and developed by them. This code, in combination with notes taken at the course, will form a package which will enable attendees to implement all the methods discussed during the course.

RF coils: Design, build and characterise your own

This course runs from introductory to advanced levels. It is primarily intended for scientists and engineers who have a basic knowledge of mathematics and simple electrical circuits. However, the course also reaches out to clinicians, experienced radiographers, application specialists and other MR users interested in gaining a better insight into the traits of RF coil technology. Attendees should have a working knowledge of magnetic resonance basics. The course balance lectures with practical sessions including RF coil design, simulation of electromagnetic fields, building your own coils, safety evaluation and coil characterisation.

fMRI and optogenetics: Probing networks in the animal brain

The course is intended for PhD students, scientists and clinicians working with fMRI, who want to extend their work to include animal models, optogenetics and/or (optical) neurophysiological readouts. Likewise, this course addresses neurophysiologist, who work with optogenetics and/or are familiar with neurophysiological readouts and want to extend their work to include fMRI. Since the course addresses an audience from several different disciplines, each methodology will be introduced from a basic level and will be developed to its state-of-the-art with respect to their combination for multimodal readout of brain activity.

Create your own echo: How to generate, calculate and manipulate echoes

This course is suited for established MR physicists, engineers, and other scientists with several years of direct experience in performing MRI applications and/or MRI technological research and development. The advanced course intends to provide a deeper understanding and mathematical description of state-of-the-art, rapid imaging principles.

Diffusion weighted MR spectroscopy

This course is intended for MR physicists, other scientists and graduate students who already have experience in basic MR methods and knowledge of MRI and MRS acquisition principles, and who wish to gain knowledge on diffusion weighted MRS acquisition, analysis and modelling techniques and incorporate DWS in their basic or clinical research protocols.

Hands-on experience in acquisition of DWS data on phantoms and human subjects will be provided throughout the course, and all experiments will be performed on the Philips 3T and 7T systems available at the MRI center. This course is NOT vendor-specific, and participants are encouraged to implement the principles taught in this course to any MR system available to them.

The post-processing, analysis and modelling code provided to the participants will be coded in MATLAB, and thus acquaintance with MATLAB is advantageous. Attendees without any MATLAB experience should have other programming experience and be willing to work with MATLAB. Attendees will be able to process and analyse the data they acquired in the hands-on acquisition stage, and at the end of the course, they will be able to take with them the MATLAB code that has been provided and developed by them. This code, in combination with notes taken at the course, will form a package which will enable attendees to implement all the methods discussed during the course on the platforms available to them.

Susceptibility weighted imaging and quantitative mapping

This course is intended for MR physicists, basic scientists and clinicians who have a working knowledge of magnetic resonance basics and who wish to extend their knowledge on qualitative and quantitative susceptibility mapping. Specific considerations for clinical applications will be discussed. This course will also integrate excursions to a SQUID magnetometer and mass spectrometer for assessing trace metals.

In vivo MRI and MRS with X-nuclei

The course is intended for MR scientists at an intermediate level with prior knowledge and/or experience with proton MRI or MRS.

Acquisition strategies for hyperpolarised spin systems: Spectral, spatial and temporal

The course is aimed at post-graduate and post-doctoral MR scientists interested in learning about acquisition strategies for NMR and MRI of hyperpolarised spin systems. A solid background in MR physics and imaging is assumed. It is not a requirement to have experience with hyperpolarisation or imaging of hyperpolarised spin systems. The course moves quickly from introductory to advanced methods over the three days. Reading material to prepare will be provided to allow students to familiarise themselves with the course curriculum. Amble time will be provided to ask questions and discuss with the faculty. Knowledge of MATLAB will be advantageous.

Resting state fMRI - basic concepts, methods & applications

May 19–21, 2014
Department of Psychology
University of Cambridge
United Kingdom

Course and local organiser:

Martin Walter
Leibniz Institute for Neurobiology
Magdeburg/DE

Local organisers:

Mika Rubinov
University of Cambridge
Cambridge/UK

Ilya Veer
Charité Universitätsmedizin
Berlin/DE

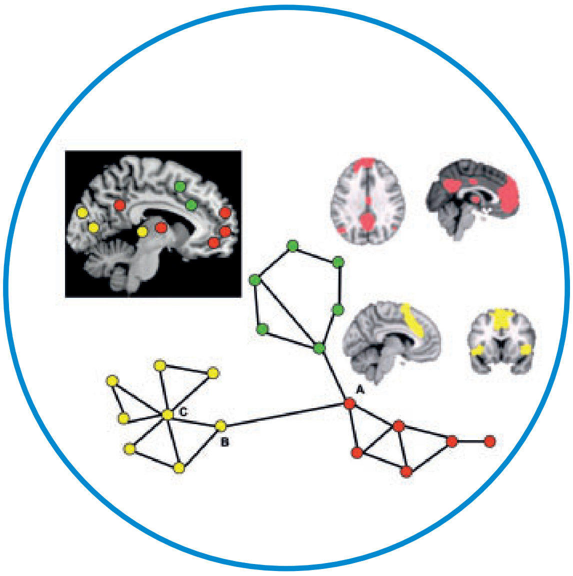
Preliminary faculty:

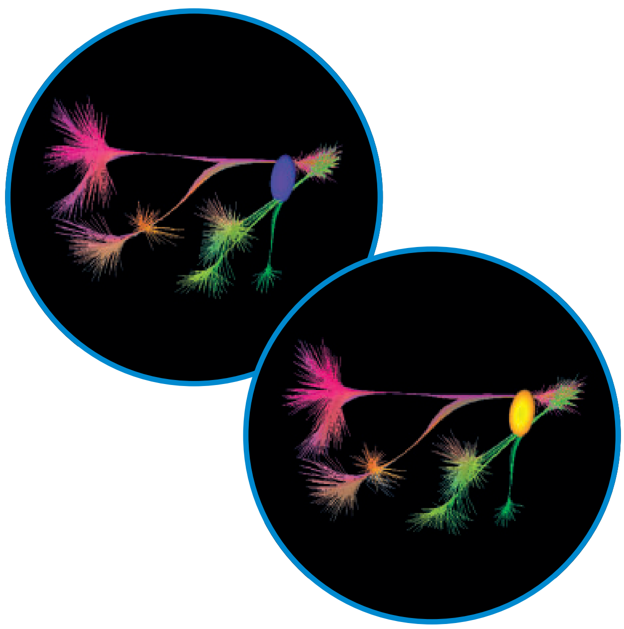
C. Chang, P. Fransson, V. Kiviniemi, M.Rubinov, I. Veer, M. Walter

Course description

Resting state fMRI, focusing on temporal characteristics and spatial organisation of spontaneous low frequency fluctuations of BOLD signals, has become a hot topic in current neuro-scientific research. Unbiased investigations of a large set of brain regions allow for network assessments and quantification of brain activity independent from subjects performance. The simple experimental setup makes it ideal for large-scale multi-center investigations, and the short duration and low demand on participants support its potential especially for clinical applications.

This three-day course aims to provide the background to access the field of resting state fMRI and to build upon for own resting state experiments. The format has been successfully developed as an educational workshop for researchers with background on fMRI. The attendees will learn about the history, the most important critical limitations, and current issues under debate, such as treatment of physiological and global signals. Next to practical training on how to perform network analysis (using seed-based correlations, ICA, and graph analysis), we will focus on differentiating the pros and cons of individual analysis strategies and provide examples for their applications in clinical samples and healthy populations. Given the special importance for current resting state investigations, we will deepen our understanding on the definition and the functional role of the default mode network.





Learning objectives

What is resting state fMRI?

- How do we acquire the data?
- What is the impact of instructions?
- What discerns resting state activity from other types of noise?
- Which are the frequency characteristics of current resting state analysis?

How do we process rs-fMRI data?

- What are basic analysis strategies of local and interregional activity?
- How do we treat physiological noise?
- What are the effects of global mean regression?
- What happens to rs-fluctuations during anesthesia?

What is connectivity?

- What is functional versus structural connectivity?
- What is discerned: Cross correlation, granger causality, standard seed-based approaches, or (semi) partial correlation?
- How can we use rs-fMRI to parcellate the brain?
- What are local low frequency spontaneous fluctuations (LFSF)?
- What are (f)ALFF, ReHo or Hurst characteristics?
- How stable are connectivities of local LFSF's?

What are brain networks?

- What are functional networks of the brain?
- How do we use ICA and what is it good for?
- What are other network approaches?
- How do I analyse graph properties during rest?

What is the default mode network?

- What are task positive and task negative networks?
- What are functions of the default mode network?
- How do we assess within and between network activities?

What is ongoing activity?

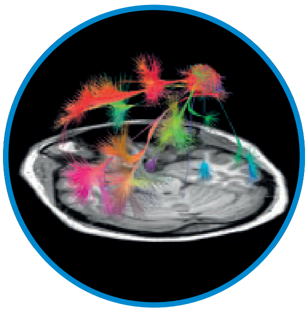
- How are resting state fluctuations and attention related?
- How can we use LFSF's in task-based fMRI?
- How are EEG characteristics represented in rs-fMRI?
- What is the effect of consciousness or wakefulness?

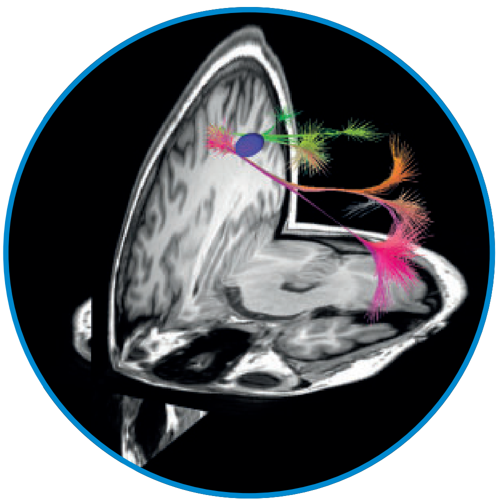
What about interindividual variability?

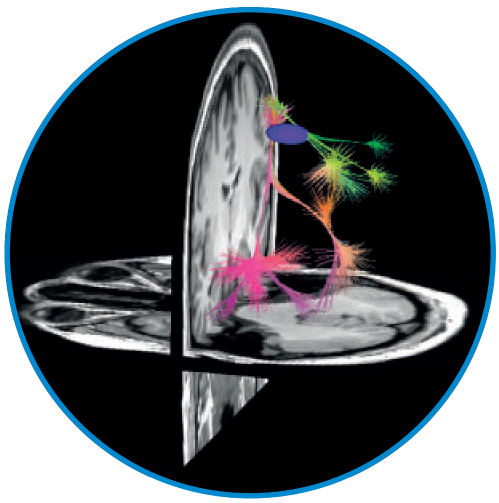
- What is reliable, what stable and what changes in rs-fMRI?
- What are dynamic properties of connectivity?
- Which pharmacological effects do we know?
- How is brain development related to its resting state?
- What other influences change LFSF's?

Which clinical aspects can we investigate?

- What are robust findings of abnormal resting state behaviour in patients?
- What is the perfect clinical resting state experiment?
- How can we use rs-fMRI in diagnosis and monitoring of patients?
- What needs to be solved for multicentre approaches using resting state fMRI?







Parallel Imaging: Basic and advanced transmission and reception concepts

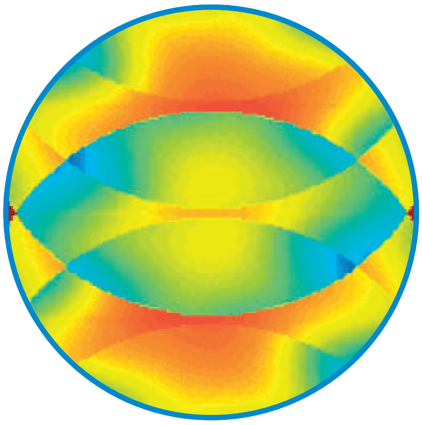
June 12–14, 2014
Kolping Haus
Würzburg, Germany

Course and local organiser:

Felix Breuer
Research Center Magnetic Resonance Bavaria (MRB)
Würzburg/DE

Preliminary faculty:

M. Blaimer, F. Breuer, S. Kozerke, S. Malik, N.N.



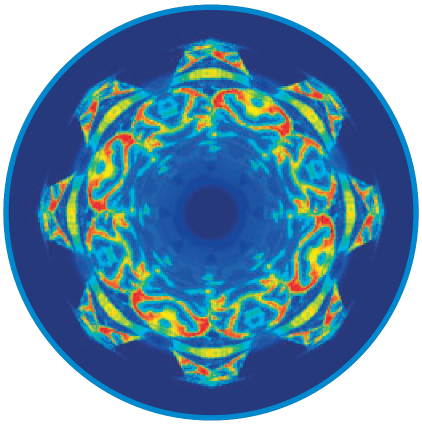
Course description

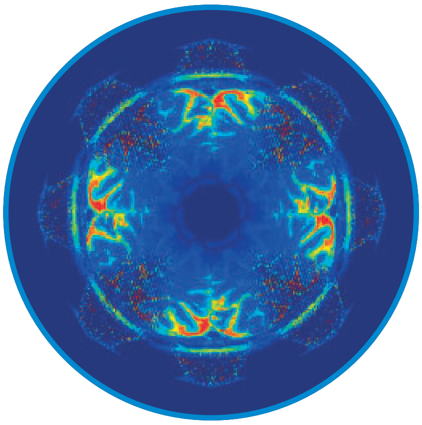
This course is designed to provide a strong practical foundation in the principles of parallel magnetic resonance imaging. Parallel Imaging (PI) is now an integral part of many clinical MRI exams. The concepts and methods of PI are informing research in many disparate aspects of MRI. This course is aimed at PhD students and scientists new to Parallel Imaging who wish to gain a working knowledge of parallel magnetic resonance to underpin their work. The course will be split in two parts, with approximately half the time spent attending lectures and the other half doing practical MATLAB tutorial exercises. We will provide computers and software licenses for the duration of the course.

The course will cover image reconstruction from multiple coils starting with an image domain view (e.g. SENSE) and moving quickly to a k-space perspective (e.g. GRAPPA). We will then look at more advanced methods; non-cartesian Parallel Imaging and many of the mathematical tools used in these reconstruction algorithms. We will look at allied methods in particular spatio-temporal undersampling and subsequent reconstructions (e.g. k-t SENSE) along with the use of multiple transmit coils (Parallel Transmit). In addition, an introduction to the Compressed Sensing (CS) concept will be given. Finally we will look to the future and discuss how multi-channel MRI may impact on future directions in MRI.

An integral part of the course will be the MATLAB tutorials where attendees will be able to work through example code provided for them. These examples will demonstrate and enhance their understanding of the concepts discussed throughout the course. Exercises will be set where attendees will modify this code to develop new examples and functionality. At the end of the course they will be free to take this code away with them.

Some previous exposure to MATLAB is preferable but not mandatory. Those participants who have not used MATLAB should have some programming experience. All participants will be expected to know essential MR physics. A working knowledge of image acquisition methods and k-space is essential.





Learning objectives

Image domain Parallel Imaging

- Define the basic reconstruction problem
- Reconstruct full images from aliased images
- Explore the effects of coil coupling on the reconstruction
- Calculate and measure reconstruction quality

K-space Parallel Imaging

- Relate image domain and k-space methods
- Assess costs and benefits of image domain and k-space methods
- Calculate and measure reconstruction quality

Coils and calibration

- Understand how coil calibration is achieved
- Compare auto-calibration and pre-calibration approaches (assessing costs and benefits)
- Establish design criteria for Parallel Imaging array coils
- Demonstrate how coil calibration errors affect reconstruction

Non-cartesian Parallel Imaging

- Define the reconstruction problem
- Review mathematical methods used in reconstruction
- Reconstruct non-uniformly sampled data with iterative methods (CG SENSE)
- Reconstruct non-uniformly sampled data in k-space

Spatio-temporal undersampling and reconstruction

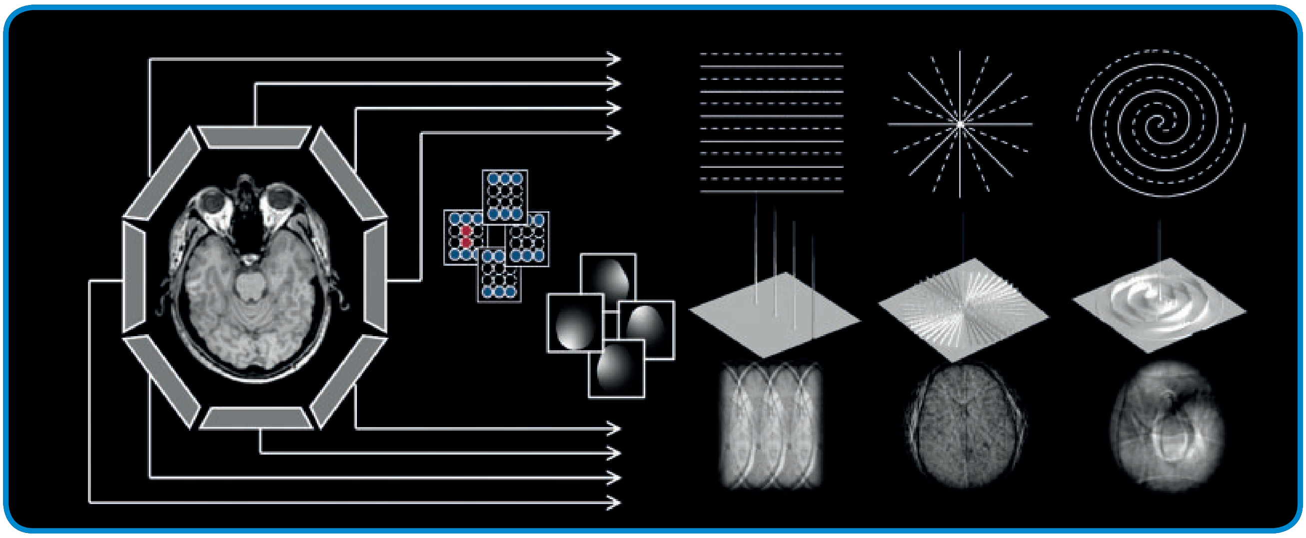
- Compare reconstruction techniques e.g. k-t SENSE, k-t GRAPPA, TSENSE, x-f choice
- Properties of calibration data
- Calculating and measuring reconstruction quality

Parallel transmission

- The small tip angle approximation
- Generating spatially modulated excitations using array coils
- Coil calibration for parallel transmission
- Costs and benefits of parallel transmission

Future Directions in multi-channel MRI

- Where is multi-channel MRI taking us?
- Compressed Sensing (CS)



RF coils:
Design, build and characterise your own

June 17–19, 2014
Berlin Ultrahigh Field Facility (B.U.F.F.)
Max-Delbrueck Center for Molecular Medicine
Berlin, Germany

Course organisers:

Thoralf Niendorf
Berlin Ultrahigh Field Facility (B.U.F.F.)
Max-Delbrueck Center for Molecular Medicine
Berlin/DE

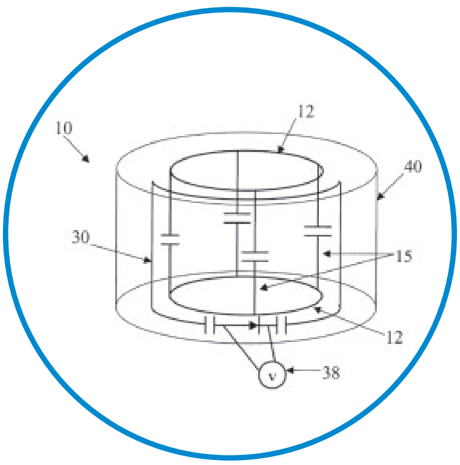
Andrew Webb
C.J. Gorter Center for High Field MRI Leiden
University Medical Center (LUMC)
Leiden/NL

Local organiser:

Thoralf Niendorf
Berlin Ultrahigh Field Facility (B.U.F.F.)
Max-Delbrueck Center for Molecular Medicine
Berlin/DE

Preliminary faculty:

S. Aussenhofer, A. Graessl, S. Gunamony, W. Hoffmann, O. Kraus, A. Kühne, M. del Mar Miñana, T. Niendorf, E. Oberacker, C. Oezerdem, H. Pfeiffer, J. Rieger, D. Santoro, C. Thalhammer, H. Waiczies, P. Waxmann, A. Webb, F. Wetterling, L. Winter, T. Wittig

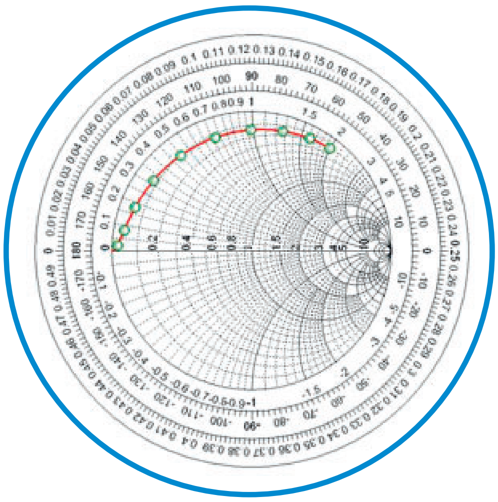


Course description

This course is designed to provide a theoretical and practical guide to RF coil design for animal and human MR systems. Simple tools for electrical circuit analysis will be introduced, followed by practical design of simple geometries such as surface coils. The participants will then design and construct a coil with their chosen dimensions and frequency of operation. In the second stage, the design of volume coils will be introduced from a theoretical basis, software for modelling these coils discussed, and again the participants can choose which type of coil to design during the practical session. Finally, advanced topics such as multi-tuned coils and phased arrays will be introduced, designed and tested.

In addition to the large degree of practical work, the course will also include a substantial amount of time that will be spent on exercises, which are intended to enhance the understanding of basic and advanced topics and will be performed in small participant groups under guidance of the lecturers.

Since participants will construct their own coil this course is limited to maximal 25 participants.



Learning objectives

RF circuit design

- High frequency behaviour of lumped elements
- Concepts of resonance and resonant circuits
- Impedance matching for maximum power transfer
- Baluns and cable traps
- Multiple-tuned circuits
- Choice of suitable components
- Concepts for coil decoupling

Hardware for RF testing

- Network analyser operation
- Resistance bridges, frequency generators
- Bench characterisation of coil performance

Simulation software

- Analysis of basic packages
- B1-homogeneity versus B1-efficiency
- SAR considerations
- High frequency RF effects

Advanced coils

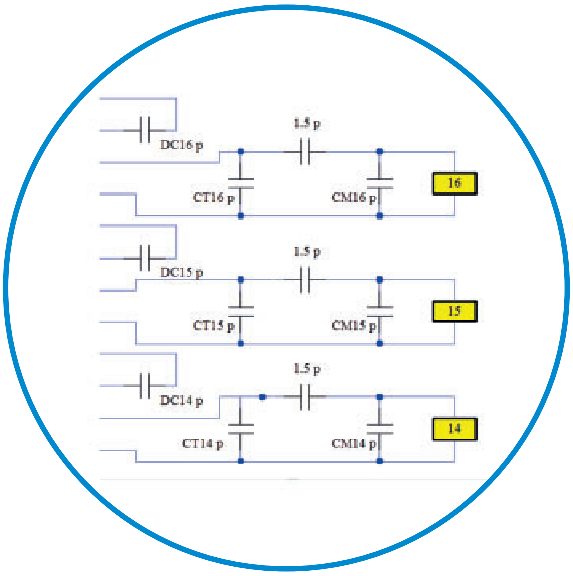
- Birdcage, loop structures, radiative antenna, dipole elements, TEM coils
- Phased arrays

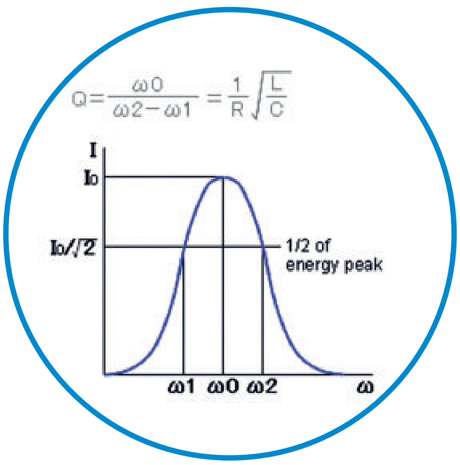
Practical design and construction

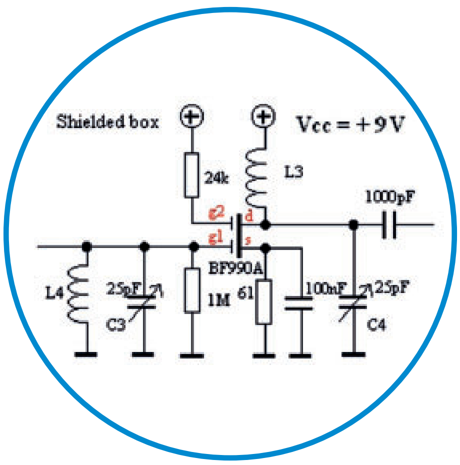
- Surface coil and/or solenoidal coil
- Birdcage volume resonator
- Double-tuned RF coil

RF coil characterisation

- Decoupling and noise correlation
- Coil sensitivity profile, B1-mapping and B1-shimming
- Parallel Imaging performance
- Signal-noise ratio performance







fMRI and optogenetics: Probing networks in the animal brain

NEW!

June 25–27, 2014
University Hospital Münster
Germany

Course organisers:

Cornelius Faber
Department of Clinical Radiology,
Translational Research Imaging Center
University Hospital Münster/DE

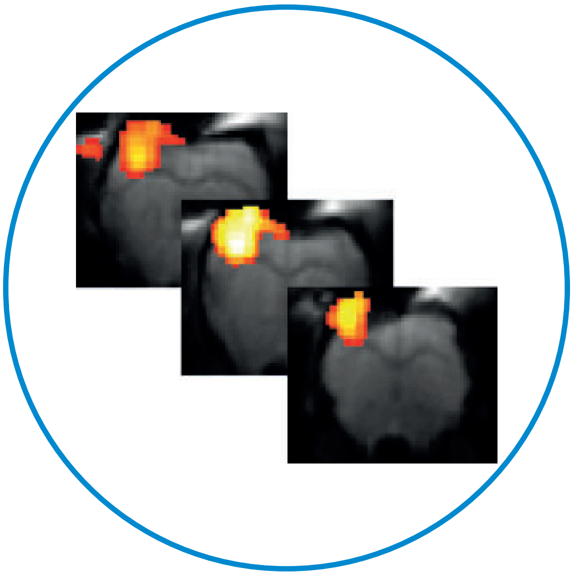
Albrecht Stroh
Research Group Molecular Imaging and Optogenetics
Institute for Microscopic Anatomy and Neurobiology
Johannes Gutenberg-University Mainz/DE

Local organiser:

Ingrid Fielding
Department of Clinical Radiology
Translational Research Imaging Center
University Hospital Münster/DE

Preliminary faculty:

C. Faber, M. Hoehn, I. Kahn, U. Lindauer, E. Rosales, F. Schmid, M. Schwalm, A. Stroh, L. Wachsmuth, X. Yu



Course description

Functional magnetic resonance imaging (fMRI) in small animals has become a key tool in experimental neuroscience and is more and more widely used. The same is true for optogenetics, which has become an essential neurophysiological method, allowing cell- and region-specific control of neuronal activity. fMRI measures the BOLD effect that represents the hemodynamic response to brain activity and is related to neural activity by the neurovascular coupling. Optogenetics requires the transduction of postmitotic neurons, using mainly viral tools, with light sensitive ion channels for neuronal excitation, and light-driven ion pumps for neuronal inhibition.

The course will address basic and advanced aspects of fMRI and optogenetics in rodents as well as basic aspects of neurophysiology and networks of the brain. Lectures will provide basic knowledge about fMRI methods, including analysis routines. Key aspects of the neurophysiological basis of the fMRI signal (neurovascular coupling) will be discussed, as well as neuronal network oscillations in health and disease. The major aspects of appropriate animal handling, anaesthesia, and of monitoring and maintaining a stable physiological state during imaging will be explained. All key steps needed for the implementation of an optogenetic approach, including choice of opsin, delivery method, control of functional expression and optical stimulation paradigms will be introduced.

The course will furthermore provide a basic understanding on the main neuronal networks and their function.
Regarding combined stimulation and acquisition, we will show the combination of fMRI with optical methods for neuronal control (optogenetics) as well as optical readout of neuronal activity (optical Ca^{2+} recordings).
Finally, applications of (f)MRI in animal models of neurological disease will be presented.

The course is intended for students, scientists and clinicians working with fMRI, who want to extend their work to include animal models, optogenetics and/or (optical) neurophysiological readouts. Likewise, this course addresses neurophysiologist, who work with optogenetics and/or are familiar with neurophysiological readouts and want to extend their work to include fMRI.

Learning objectives

fMRI basics

- Introduction to MRI as noninvasive imaging method
- MRI methods to study the brain (BOLD-fMRI, ASL, MEMRI)
- Analysis of fMRI data

Optogenetics basics

- Opsins (light-gated channels, light-driven pumps)
- Viral delivery and cell type specificity
- Stimulation techniques

Neurophysiology basics and methods

- Neurovascular coupling
- Networks of the brain (thalamocortical oscillations)
- Optical and electric detection of neuronal activity (Ca^{2+} recordings, LFP)

Small animal MRI

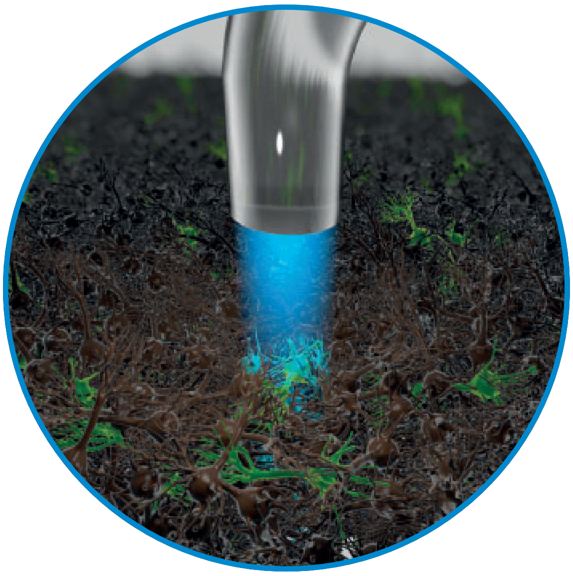
- Rodent physiology and monitoring (animal handling, procedures)
- Anaesthesia
- Sensory stimulation (forepaw, visual)

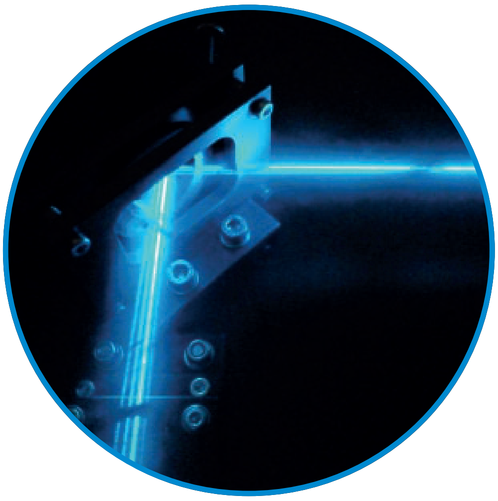
Combined readout and stimulation

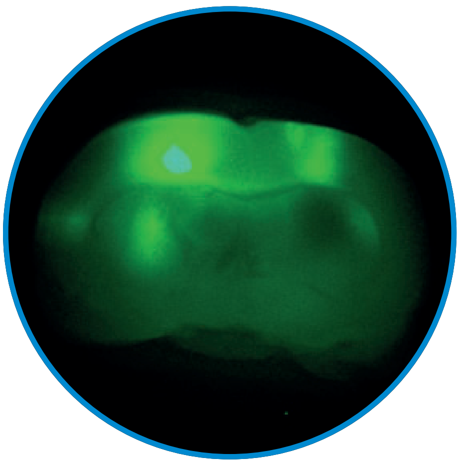
- ofMRI
- optical Ca^{2+}-ofMRI
- optical Ca^{2+} +LFP

Applications

- Epilepsy
- Stroke
- Neurodegenerative disease







Create your own echo: How to generate, calculate and manipulate echoes

September 17–19, 2014
Klinikum rechts der Isar
Technical University Munich
Germany

Course organiser:

Klaus Scheffler
Max-Planck-Institute for Biological Cybernetics
Tübingen/DE
Department of Biomedical Magnetic Resonance
University of Tübingen/DE

Local organiser:

Carl Ganter
Klinikum rechts der Isar
Technische Universität München/DE

Preliminary faculty:

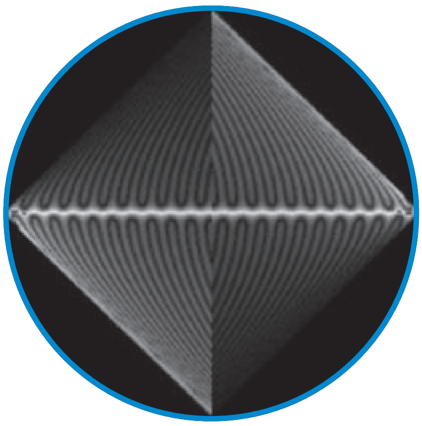
O. Bieri, C. Ganter, K. Scheffler, M. Weigel

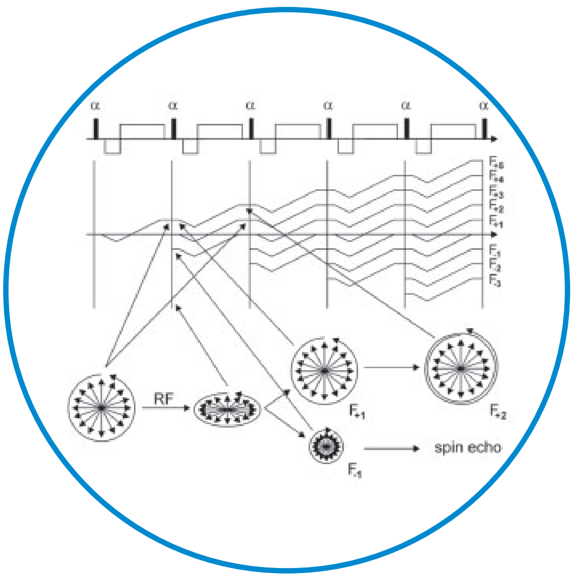
Course description

The design and understanding of rapid imaging sequences seems to be a carefully sealed and treasured secret. A train of RF pulses and gradient pulses produce an unmanageable amount of echoes, and these echoes have to be combined and selected very meticulously to produce a useful signal for rapid imaging. How big should we choose the spoiler gradient within a gradient echo sequence, and what do we spoil? Can we use a HyperEcho to reverse a gradient echo sequence? What is the steady state and its resulting contrast?

After very successful courses held in Basel, London, Essen, Magdeburg and Tübingen this course will be repeated in Munich in 2014. The lectures are designed to provide a general and formal framework for the description and understanding of rapid multi-pulse experiments based on the Bloch equations and its Fourier-analogy, the extended phase graph in k-space.

This advanced course is aimed at established MR physicists, engineers, and other communities with several years of direct and practical experience in MRI applications and/or MRI technological research and development, who seek a deeper understanding of rapid imaging principles.





Learning objectives

Description of magnetisation in spatial and Fourier domain

- Bloch equations, applied to simple gradient and spin echo techniques
- Description of magnetisation as Fourier series, interpretation of Fourier coefficients as population of states
- Theory of partitions/states
- Description of spin echo, stimulated echo, higher order echoes with extended phase graph
- Calculation of echo amplitudes

Signal formation in rapid gradient echo sequences

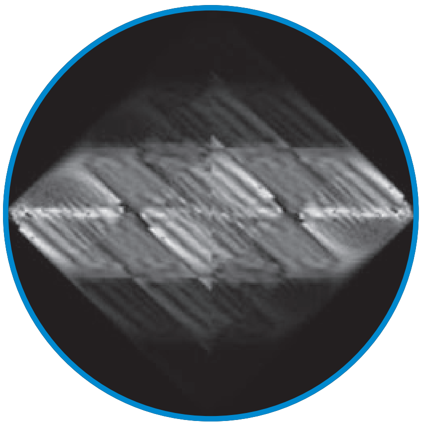
- The stopped pulse experiment
- Conditions and properties of the steady state
- Description of the steady state in spatial and Fourier domain
- Types of steady state sequences
- Double echo techniques
- Echo shifted techniques
- Contrast of rapid gradient echo techniques
- RF-spoiling

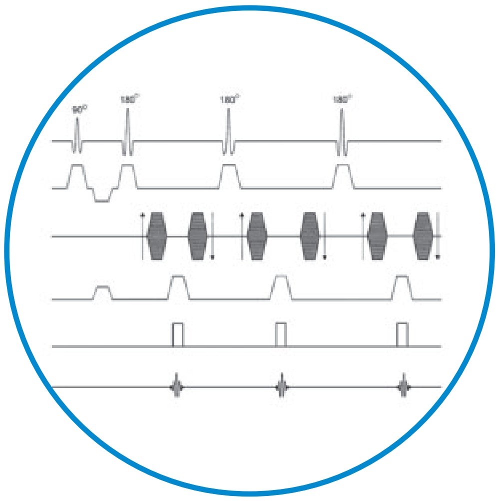
Signal formation in rapid spin echo sequences

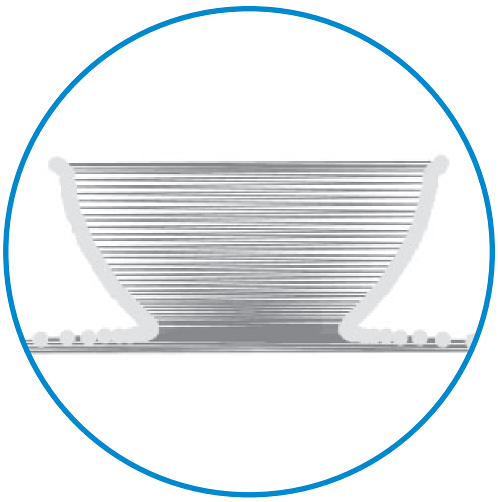
- CPMG and non-CPMG condition
- CPMG with reduced refocusing flip angles
- Pseudo steady state
- Preparation of defined echo amplitudes
- Static pseudo steady state
- Hyper echo
- Implementation of rapid CPMG sequences

Special rapid imaging techniques

- Gradient and spin echoes: GRASE
- Missing pulse techniques
- Motion, diffusion, and flow sensitivity of spin- and gradient echoes
- Single shot techniques
- Major clinical applications of rapid imaging techniques
- A summary of possible contrasts







Diffusion weighted MR spectroscopy: How to acquire, process, analyse and model metabolite diffusion weighted data

NEW!

September 22–24, 2014
Leiden University Medical Center (LUMC) Netherlands

Course and local organisers:

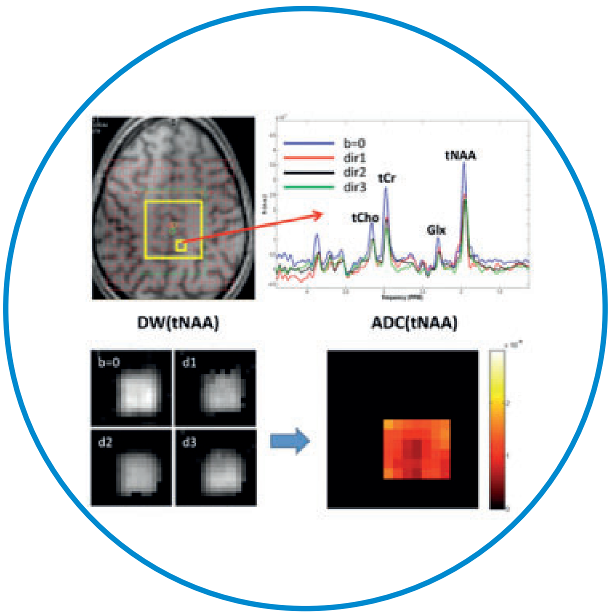
Itamar Ronen
C.J. Gorter Center for High Field MRI
Leiden University Medical Center (LUMC)
Leiden/NL

Stefan Posse
Department of Neurology
University of New Mexico School of Medicine,
Albuquerque/USA

Julien Valette
Molecular Imaging Research Centre, CEA
Fontenay-aux-Roses/FR

Preliminary faculty:

F. Branzoli, H. Kan, S. Posse, I. Ronen, J. Valette, N.N.



Course description

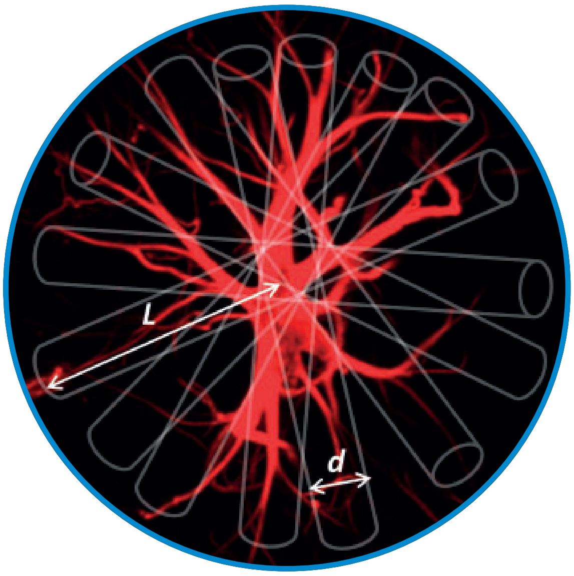
This course is designed to provide a strong practical foundation in the principles of diffusion weighted magnetic resonance spectroscopy (DWS) in all of its aspects. DWS provides unique cell-specific and compartment-specific microstructural information based on the diffusion properties of intracellular metabolites in neural and muscle tissue, and it thus complements more sensitive but less specific methods such as diffusion tensor imaging (DTI). In clinical and pre-clinical research, incorporation of DWS in a comprehensive protocol aimed at microstructural characterisation of tissue allows untangle the effect of multiple pathological processes on tissue microstructure, and thus significantly increases the explanatory power of MR for the overall pathology.

At present, however, incorporation of DWS in standard protocols poses significant challenges: Robust DWS sequences are not offered on any of the commercially available MR scanners. DWS data acquisition is highly susceptible to physiological fluctuations, and the DWS signal is strongly affected by e.g. eddy currents generated by the strong diffusion weighting gradients and cardiac pulsation. As a result, the robustness and reproducibility of DWS strongly depends on a highly specialised pipeline of acquisition and processing that takes into account as many possible adverse effects as possible.

The course will cover the entire process of generating robust and reproducible single-voxel and spectroscopic imaging DWS data. We will present the pulse sequences used in DWS, and the optimal circumstances for using each of these, based on the goal of the study. We will then discuss the delicate role of water suppression and the residual water signal as a handle for some of the post-hoc signal corrections. We will discuss the role of phase/amplitude navigators in DW-MRSI and strategies for real time re-acquisition of corrupted k-space DW data. Strategies and techniques for eddy current corrections will be discussed, including e.g. the use of singular value decomposition of the residual water signal. Ultimately, various modelling strategies of DWS data will be presented, as well as how to incorporate information from other modalities such as DTI and tissue segmentation into the modelling of DWS data.

The course will consist of two parts: In the first, a series of lectures will cover the main methodological aspects in DWS, from acquisition to analysis and modelling, and emerging neuroscience and clinical research applications. The second part is a fully hands-on section, where attendees will plan and execute a DWS experiment, export the data and process it with a comprehensive MATLAB code for DWS signal processing that will be provided to them, and finally will analyse the data to generate diffusion properties of the metabolites they measured in the experiment. DWS experiments will be performed on the two available platforms at the Gorter Center – the 3T and 7T MRI scanners. For the processing, attendees will be able to use the computers available at the center, or their own laptops.

Attendees of the course are expected to have a good background in MR physics and be familiar with basic concepts in diffusion MR and in vivo MRS. A basic knowledge of MATLAB is preferred, and an acquaintance with principles of signal processing is advantageous.



Learning objectives

DWS pulse sequences

- Optimised incorporation of diffusion weighting in standard SV-MRS sequences
- Minimisation of eddy currents and cross-terms with background gradients
- Isotropic DWS
- 2D-DW-CSI: Challenges and the strategies for the use of navigators to minimise signal fluctuations
- Non-proton DWS: ^{31}P-DWS and its special challenges
- Designing the right DWS experiment to answer a specific question

Post-processing of DWS data

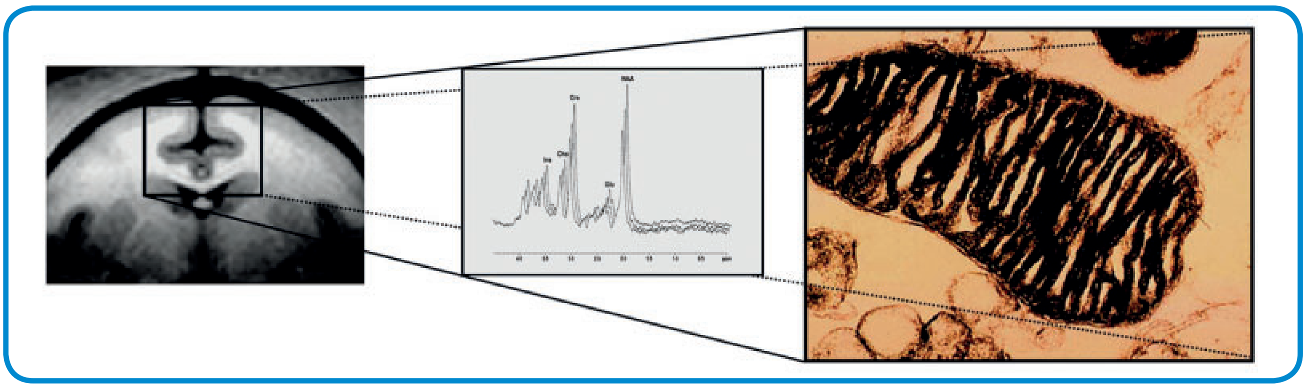
- Major sources of error in DWS data and their correction
- Strategies for optimal eddy current correction for SV and 2D-DW-CSI data
- The subtle art of cardiac triggering and other prospective motion correction strategies

Modelling and analysis

- Obtaining standard diffusion metrics from DWS data
- Incorporation of models of cellular geometry for obtaining further information about intracellular tortuosity and microstructure
- Incorporation of data from other MR modalities (DTI) for refining and increasing the amount of microstructural information from DWS

Emerging neuroscience and clinical research applications

- Attendees and faculty will present and discuss emerging DWS applications in basic science and clinical research



Susceptibility weighted imaging and quantitative mapping

NEW!

November 17–19, 2014
Department of Neurology
Medical University of Graz
Austria

Course organisers:

Jürgen R. Reichenbach
Medical Physics Group
University of Jena/DE

Stefan Ropele
Neuroimaging Research Unit
Medical University of Graz/AT

Local organisers:

Christian Langkammer
Neuroimaging Research Unit
Medical University of Graz/AT

Stefan Ropele
Neuroimaging Research Unit
Medical University of Graz/AT

Preliminary faculty:

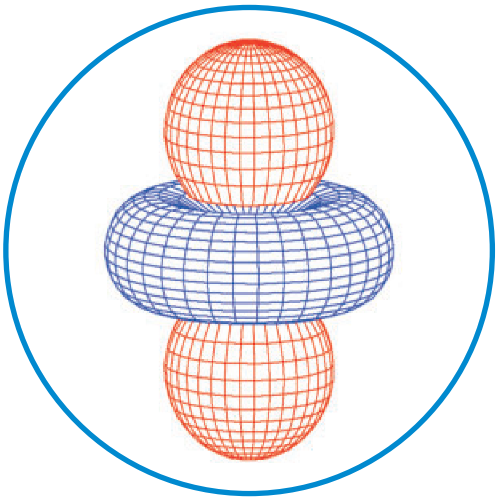
N.N.

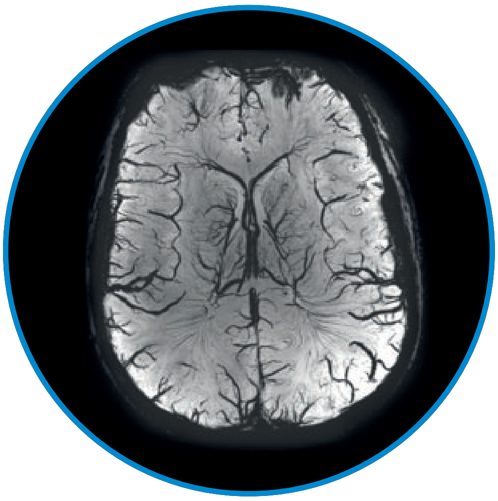
Course description

Magnetic susceptibility is a fundamental physical property, which can significantly affect MR image contrast. Susceptibility weighted imaging (SWI), which was one of the first attempts to maximise this contrast, has enabled us to highlight tissue structures and compounds that can hardly be detected by conventional MRI, including iron, calcifications, small veins, blood, and bones. In recent years, impressive progress has been made in quantification of tissue susceptibility in vivo by solving the inverse problem (QSM). First clinical susceptibility mapping studies are now available and the field of new clinical applications is growing rapidly.

This course will enable interested scientists, MR physicists or PhD students to understand the concepts of SWI and QSM and their applications. The course is also suited for clinicians with interest in new clinical applications of susceptibility imaging, however basic MRI knowledge is a prerequisite to benefit from the entire course programme.

The course will address four major topics including the fundamentals of the magnetic susceptibility, pulse sequence considerations, reconstruction methods, and (pre)clinical applications. The primary teaching method will be lectures with ample room for discussions. However, the course will also integrate excursions to a SQUID magnetometer and mass spectrometer.





Learning objectives

Magnetic properties of tissue

- Be familiar with the magnetic properties of different tissue components and trace elements
- Understanding how bulk susceptibility is affected by tissue composition and microarchitecture
- Iron and myelin
- Non-MRI methods for assessing susceptibility of tissue

Susceptibility weighted MR sequences

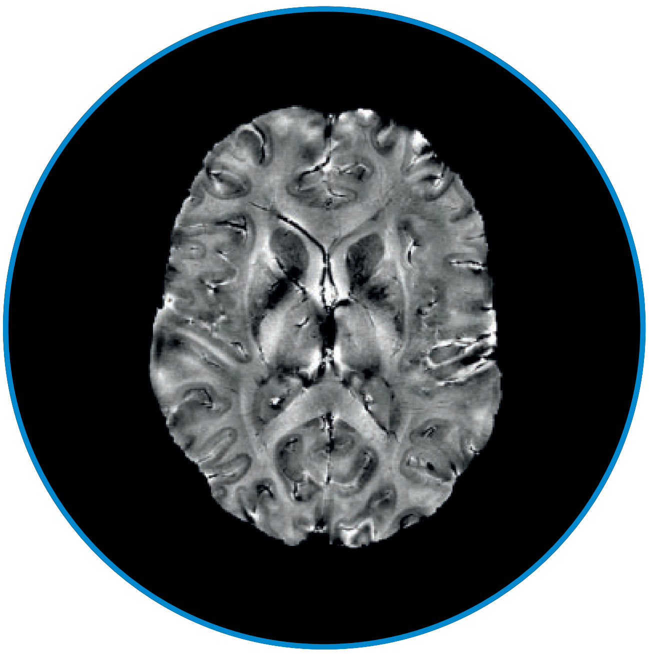
- Pulse sequence considerations
- SNR optimisations
- Impact of image resolution and voxel aspect ratio
- Combining signals from multi-coil arrays
- Effect of B0 gradients and correction schemes
- Non-cartesian sampling schemes

Reconstruction methods

- Phase unwrapping, filtering, background field removal
- Combining phase and magnitude images (SWI)
- Quantitative susceptibility mapping (QSM)
- Inversion algorithms
- Advanced mathematical methods
- Susceptibility tensor imaging

Clinical and preclinical applications

- Detection of microbleeds and calcifications
- Iron mapping in inflammatory and neurodegenerative diseases
- Assessing myelin content
- Tumor imaging
- Ischemia
- Quantification of contrast agent
- Quantitative blood oxygenation venography
- Applications outside the brain



In vivo MRI and MRS with X-nuclei

NEW!

November 25–26, 2014
University Medical Center Freiburg
Germany

Course and local organisers:

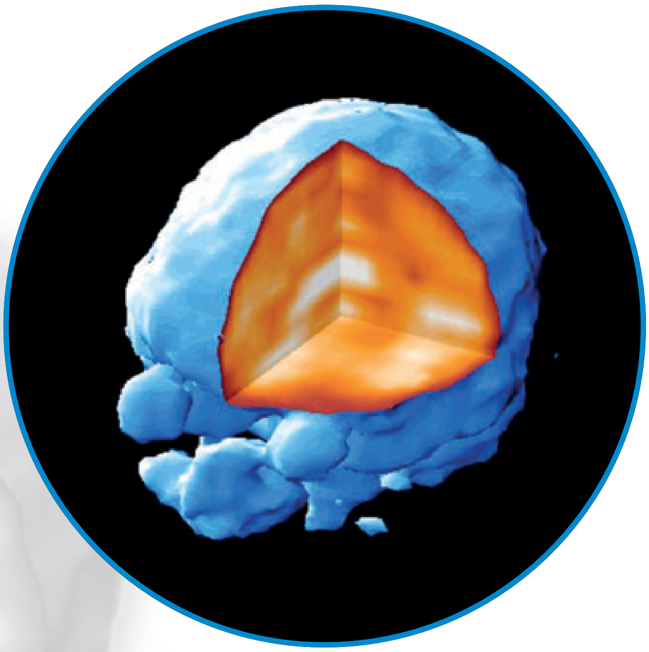
Michael Bock
Thomas Lange
Medical Physics
University Medical Center Freiburg/DE

Preliminary faculty:

D. v. Elverfeld, T. Lanz, A. Nagel, L. Schreiber, N.N.

Course description

The course will provide an in-depth insight into magnetic resonance methods that acquire signals from nuclei other than the proton. The course is intended for MR researchers at an intermediate level with prior knowledge and/or experience with proton MRI or MRS. After completion of the course participants should be familiar with the possibilities and pitfalls of X-nuclear imaging and spectroscopy.
Starting from a basic introduction into the differences and similarities of X-nuclear and proton MR, the course will cover different acquisition techniques for in vivo X-nuclei. Acquisition techniques and applications of X-nuclei such as sodium-23, phosphorus-31, carbon-13, fluorine-19, and oxygen-17 will be covered, and a brief introduction into the use of hyperpolarised nuclei will be given. The specialties of pulse sequences and RF coil hardware for X-nuclear MR will be presented, and applications for both small animal and human studies will be discussed.



Learning objectives

Introduction

- MR physics of X-nuclei
- Overview over the applications for X-nuclear MR techniques

Basic pulse sequences for X-nuclei

- Ultrashort-TE sequences
- Localisation techniques
- Decoupling and NOE
- Coherence transfer techniques

Radio-frequency coils for X-nuclei

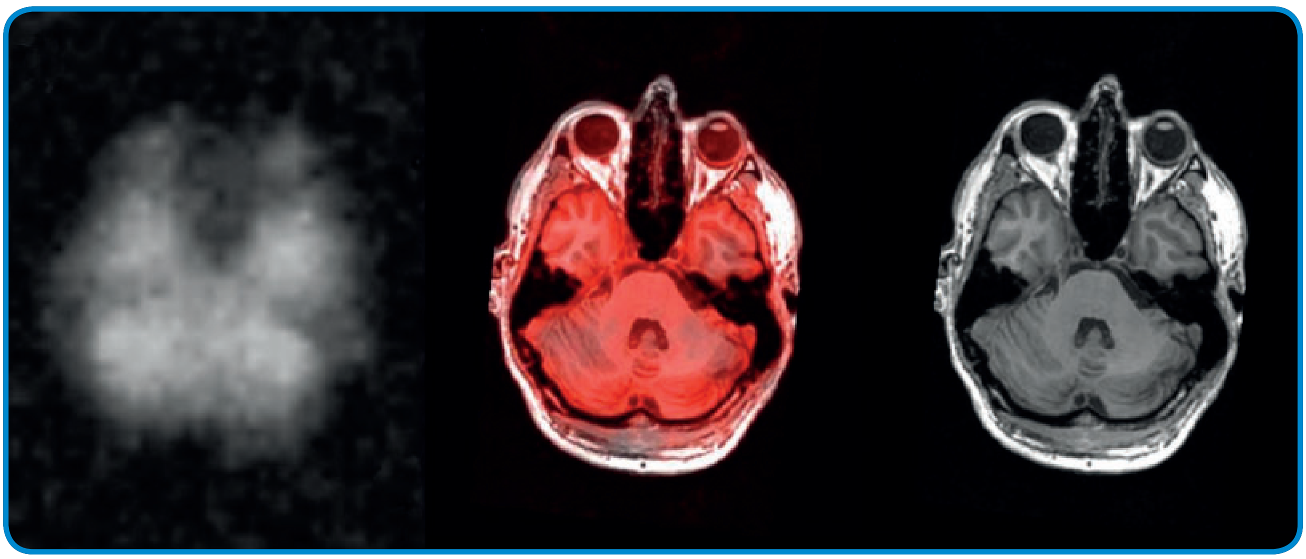
- Basic Tx/Rx coils
- Dual-tuned coils
- Special requirements for X-nuclei

A journey through the periodic table of elements

- 31P: Energy metabolism
- 23Na: Cellular vitality
- 13C: Labelling of organic substances
- 19F: Tracer studies
- 17O: Oxygen metabolism
- 3He/129Xe: Ventilation and more

Applications

- Pre-clinical studies in small animals
- Clinical studies in volunteers and patients



Acquisition strategies for hyperpolarised spin systems: Spectral, spatial and temporal

December 9–11, 2014
gate Garchinger Technologie- und Gründerzentrum GmbH
Garching, Munich
Germany

Course and local organisers:

Jan Henrik Ardenkjær-Larsen
GE Healthcare and Technical University of Denmark (DTU)
Lyngby/DK

Markus Durst
GE Global Research and Technische Universität München/DE

Axel Haase
Technische Universität München/DE

Rolf F. Schulte
GE Global Research
Garching/DE

Preliminary faculty:

J. Ardenkjær-Larsen, A. Heerschap, A. Kerr, S. Kozerke, J. Leupold, R. Schulte, J. Wild

Special activity (December 12, 2014)
The three-day course is followed by an optional extra day (December 12, 2014) with practical sessions at the hyperpolariser and MRI scanner.
Pre-registration is required.
Further information at www.esmrmb.org

Course description

Hyperpolarisation has opened up new applications of NMR and MRI. Acquisition strategies for hyperpolarised substances differ substantially from those suitable for thermally polarised samples due to the non-recoverable magnetisation.

The aim of this three-day course is to provide the participants knowledge of experimental and theoretical aspects of polarisation, magnetisation use, pulse sequence design and RF hardware for in vivo hyperpolarised MR. Different imaging strategies will be presented with emphasis on the special requirements and adaptations needed for hyperpolarisation studies. The use of specialised RF pulses will be covered as well as possibilities for accelerated acquisitions by means of Parallel Imaging and Compressed Sensing. Quantification and modelling of data are important aspects of hyperpolarisation studies and specialised methods will be described as the last part of the course.

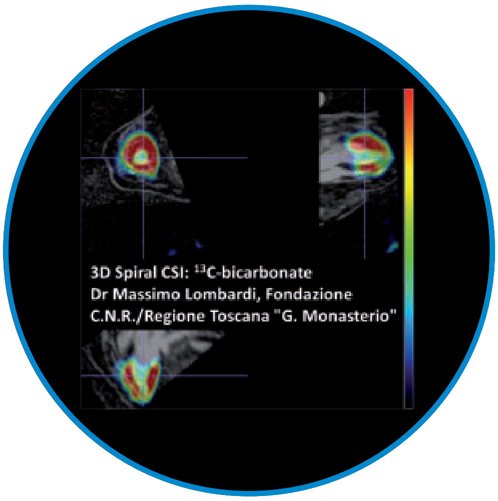
An integrated part of the course will be theoretical exercises where the participant will work in more depth and gain hands-on experience on the topics covered in the lectures. Practical MATLAB tutorial exercises will be provided. For those who do not have MATLAB we will provide computers and software licenses for the duration of the course. The students will be able to work through example code provided for them. These examples will demonstrate and enhance their understanding of the concepts discussed throughout the course. At the end of the course they will be free to take this code away with them. Some previous exposure to MATLAB is preferable, but not mandatory.

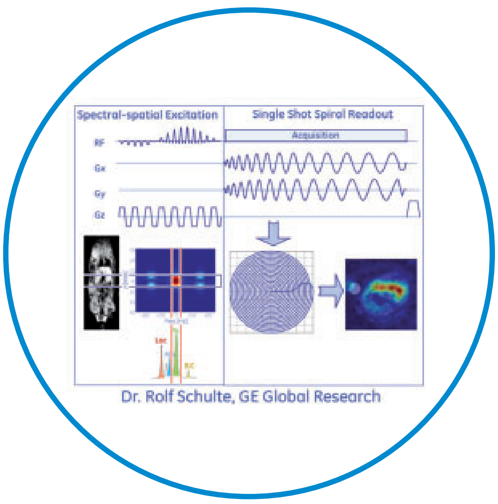
The course is aimed at post-graduate and post-doctoral MR scientists interested in learning about acquisition strategies for NMR and MRI of hyperpolarised spin systems. A solid background in MR physics is assumed. A working knowledge of image acquisition methods and k-space is essential.

Learning objectives

At the end of the course the student will be able to

- Explain the basic advantages and limitations of the different hyperpolarisation methods
- Explain the relevance of different relaxation mechanisms and their time scale
- Explain hardware (scanner) requirements for hyperpolarisation imaging
- Explain basic imaging sequences for chemical shift imaging (CSI and EPSI)
- Explain advantages and limitations of non-cartesian (radial/spiral) sequences and exploit the sparsity of the spectral dimension
- Explain the advantages and limitations of spin-echo and steady-state sequences
- Design specialised RF pulses for spectral-spatial excitation
- Select Parallel Imaging methods for hyperpolarised molecules
- Use Compressed Sensing and sparse sampling strategies efficiently
- Use methods for quantification of spectral data such as intensity, integration, frequency and time domain fitting (jMRUI, LCmodel)
- Model kinetic (temporal) data, explain exchange reactions and methods of solving the rate equations, and correct for relaxation and RF excitation
- Provide a biological interpretation of rate constants and other parameters extracted from in vivo hyperpolarisation data





Registration

In order to register for your desired course(s), please visit our website at **www.esmrmb.org**.

Please note that your registration becomes valid only upon reception of payment and confirmation by the ESMRMB Office, the latter will be available for download in the online 'MyUser Area'.

Registration

Rates refer to one course. If more than one course is booked at once, a 10% reduction will be granted.

The registration fee includes:
- Attendance of the course
- Teaching material for the course (digital syllabus)
- Coffee & Lunch
- Welcome Reception

Participants are responsible for their own travel and hotel arrangements. When making your flight bookings, please make sure that you will be able to stay for the entire course.

Terms of cancellation

In the case of cancellation of registration by the participant:

> 4 weeks before the course date: the registration fee will be refunded less 20% for administrative costs.
< 4 weeks before the course date: no refund will be granted.

If less than 20 participants register, ESMRMB reserves the right to cancel a course 4 weeks prior to its beginning, at the latest.

Registration is possible online at **www.esmrmb.org**

Registration fees

(except RF coil design course)

Early registration fees

(until 8 weeks prior to the course)

	Members**	Non-Members
Basic scientists, physicians, technicians and others with a professional degree	**€ 390**	**€ 560**
PhD students and physicians in training*	**€ 240**	**€ 335**

Late registration fees

(less than 8 weeks prior to the course)

	Members**	Non-Members
Basic scientists, physicians, technicians and others with a professional degree	**€ 510**	**€ 705**
PhD students and physicians in training*	**€ 310**	**€ 430**

Industry fee

This rate is applicable for employees/representatives of commercial companies.

€ 970

RF coils: Design, build and characterise your own

Please note that due to special requirements for this course different registration fees apply.

Early registration fees

(until 8 weeks prior to the course)

	Members**	Non-Members
Basic scientists, physicians, technicians and others with a professional degree	**€ 540**	**€ 710**
PhD students and physicians in training*	**€ 390**	**€ 485**

Late registration fees

(less than 8 weeks prior to the course)

	Members**	Non-Members
Basic scientists, physicians, technicians and others with a professional degree	**€ 640**	**€ 835**
PhD students and physicians in training*	**€ 440**	**€ 560**

Industry fee

This rate is applicable for employees/representatives of commercial companies.

€ 1,120

* PhD students and physicians in training are requested to provide a signed attestation from the head of the institution/department confirming their student/training status no later than 10 days after the registration.

** Reduced course fees are available for members in good standing who have paid their 2014 ESMRMB membership fee.