NMR SPECTROSCOPY AND IMAGING

LECTURE MODULE 20112301/02 SOSE 2017

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Lecture Module
NMR Spectroscopy and Imaging

Lectures: 70 min + 20 min. break
Exercises: 45 min Lab Course: 3 hrs

Lecture 1: Sample, Instrument, Raw Data
Organizational things, macroscopic magnetization, Energy levels, wavelength in EM spectrum, excitation, rotating frame, FID,NMR hardware

Lecture 2: Retrieving the Spectral Information
postprocessing, FFT

Exercise 1

Lecture 3: The Spin's Perspective
Chemical shift, Relaxation

Lecture 4: Spin-Spin Interactions
coupled spin systems, transition probabilities,

Lab Course 1:
Hardware, probe assembly, wobble/shim, NMR of water, artefacts of truncation/folding, filtering, baseline correction, strongly coupled spin system (citrate?), $CuSO_4$ relaxation

Lecture 5: Index Gymnastics
necessary math (operators etc.); QM of a spin (system), magnetization, RF excitation, Chap 6

Lecture 6: Describing the Spin Ensemble
density operator, (vector model?), Chap 11 levitt, chap 14, levitt, transition probabilities

Exercise 2

Lecture 7: Spin Manipulation
RF pulses, saturation, decoupling, selective excitation

Lecture 8: Hyperpolarization: SEOP
general sensitivity problem, spin-spin interaction outside magnet

Lab Course 1 (repeat)

Lecture 9: Hyperpolarization: DNP, PHIP
dynamic nuclear polarization, para-H_2 induced polarization, incl. clinical applications

Lecture 10: NMR Applications Gradients and Simple Applications
NMR applications in chemistry, medical applications: diffusion detection

Exercise 3

Lecture 11: Multi-Pulse Experiments and Water Suppression (Spin Echoes and Selective Suppressions)
Hahn echo, gradient echo, stimulated echo

Lecture 12: Localized Spectroscopy, In vivo MRS of Coupled Systems
PRESS, STEAM, CSI, applications

Exercise 4

Lecture 13: Image Encoding Concept
2D FFT, Spin Warp imaging etc, Spin Echo, Gradient Echo

Lecture 14: Basic Imaging Sequences and Contrast Generation
Repetition time, echo time, flip angle and combinations thereof

Lab Course 2:
imaging, relaxometry, HP Xe

Lecture 15: Imaging Parameter Toolbox
TSE, EPI, radial encoding

Lecture 16: Strategies for Accelerated Imaging
phase information in images, diffusion, flow artefacts

Exercise 5

Lecture 17: Contrast Agents
Gd, iron oxide, Mn, copper in complex formation

Lecture 18: Spins in Motion
invisible protons, CEST agents, pH dependent Csn-Cu complexation

Lab Course 2 (repeat)

Lecture 19: Functionalized Xenon
Xe hosts and their functionalization, Hyper-CEST NMR

Lecture 20: Limitations
sensitivity, costs, time resolution, diffusion

Exercise 6:
open questions

Exercise 1:

This exercise takes place in front of the NMR lab and includes a short overview of NMR history, a spin flip demo experiment and safety instructions for the following days.

The superconducting magnet that is used during this lab course operates at a field inductivity of 9.4 T which is ca. 200 000-times stronger than Earth's field. Handling with any ferromagnetic objects close to the magnet is strictly forbidden because of the suddenly appearing strong attraction forces and the related risk of injury. Furthermore, people with pace makers and other not explicitly allowed medical implants or other foreign objects (including, but not limited to endoprotheses, insulin pumps, and metallic chips etc. like from bullet wounds) are not allowed inside the magnet room B0.03. The following objects have to be deposited in the control room after entering the NMR lab:

- keys
- wallets (credit cards!)
- watches
- jewelry

Tools (including scissors and ball pens) are generally assumed to contain magnetic parts. Using such equipment – if at all necessary in the magnet room – is only allowed outside the 5 Gauss line. This is the area ca. 30 cm away from the magnet body.

To maintain the superconductivity in the magnet coil, it is immersed into liquid helium which is surrounded by a bath of liquid nitrogen (see Fig. 1). In the event of a so-called quench, these liquid cryogens vaporize suddenly and violently because they expand into a multiple of their liquid state volume. Oxygen from the air is then replaced and humidity condensates into dense fog. Such an event is often identified through a typical whistle noise at the overpressure release valve of the magnet. Because of the danger of asphyxiation, you are requested to leave the room <u>immediately</u> in such an emergency situation.

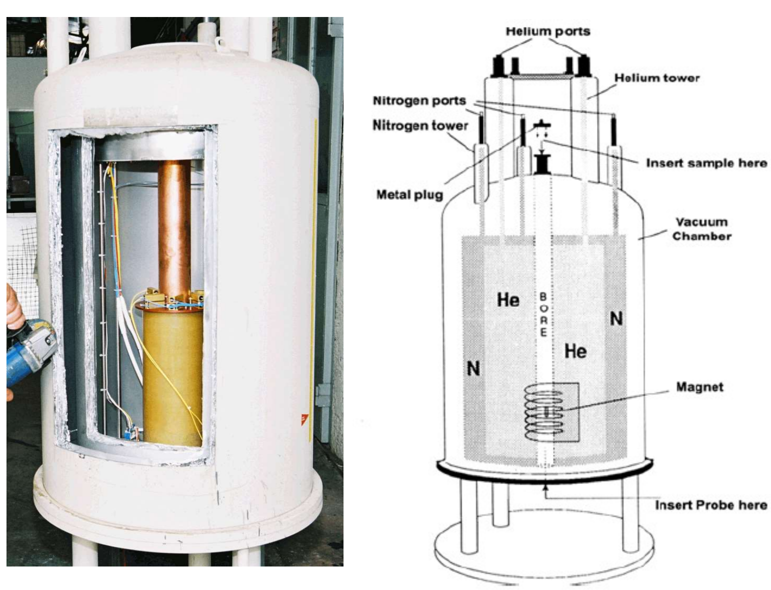

Fig. 1:
Structure of an NMR magnet

The magnet room also contains a laser setup called LEIPNIX 150 duo that is used for the production of hyperpolarized xenon. Part of this setup is a strong infrared laser with 150 W cw emission at 795 nm. Eye or skin exposure to direct or scattered laser beam has to be absolutely avoided. For this reason, the laser optics is assembled in an enclosure and can be operated without wearing any further eye protection equipment. You are not allowed to operate the hyperpolarizer without especially being instructed to do so or to manipulate anything on the enclosure of the laser setup. This will change the classification of the laser system and make the lab inaccessible to other people.

I hereby sign that I have read and understood the safety instructions concerning the NMR lab B0.03 at the FMP

Name in print ____________________________

Date ____________________________

Signature ____________________________