External photon beams: Clinical treatment

Experimental results

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- Photon sources are either isotropic or non-isotropic and they emit either monoenergetic or heterogeneous photon beams.
- An isotropic photon source produces the same photon fluence rate in all directions
- Photon spectra for a monoenergetic and a heterogeneous photon beam are shown in Fig. (a) and (b), respectively

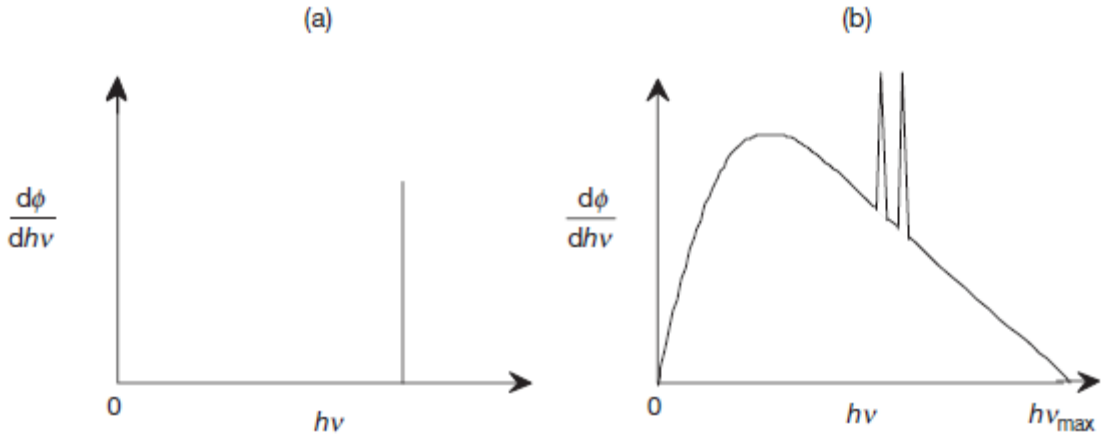
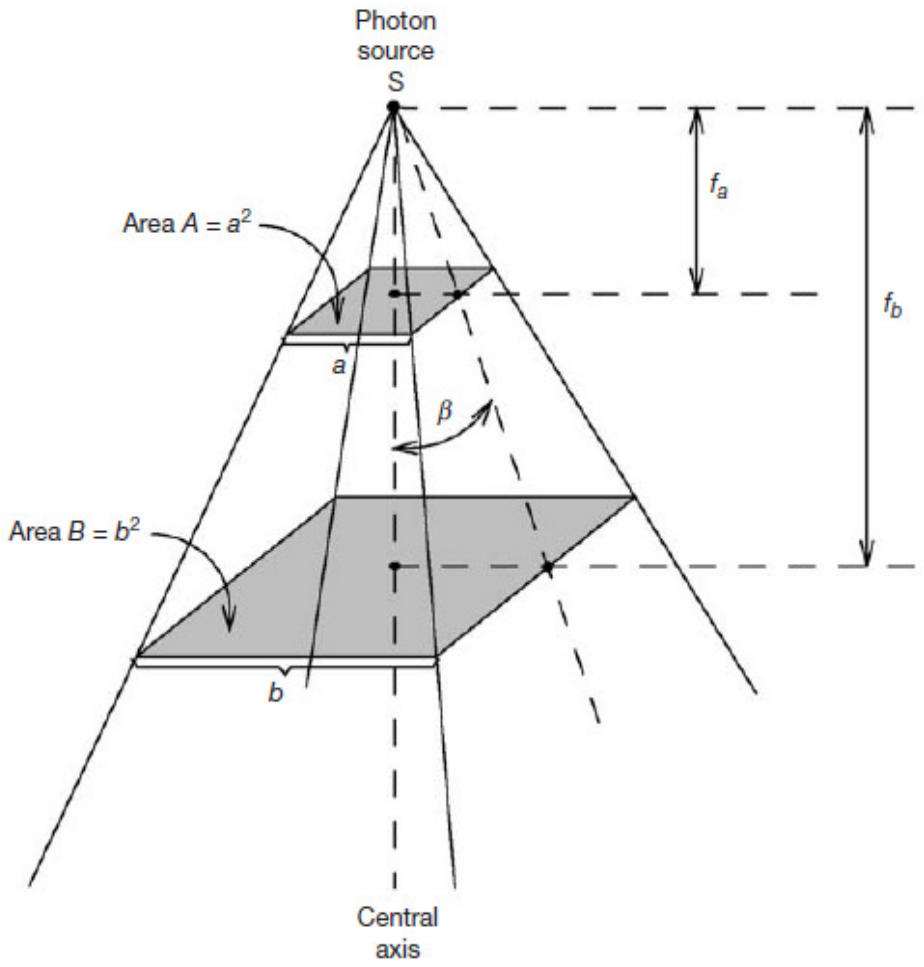


FIG. 6.1. Typical spectra for (a) monoenergetic and (b) heterogeneous photon beams.



In external beam radiotherapy, photon sources are often assumed to be point sources and the beams they produce are divergent beams

The photon fluence is inversely proportional to the square of the distance from the source.

* Inverse square law

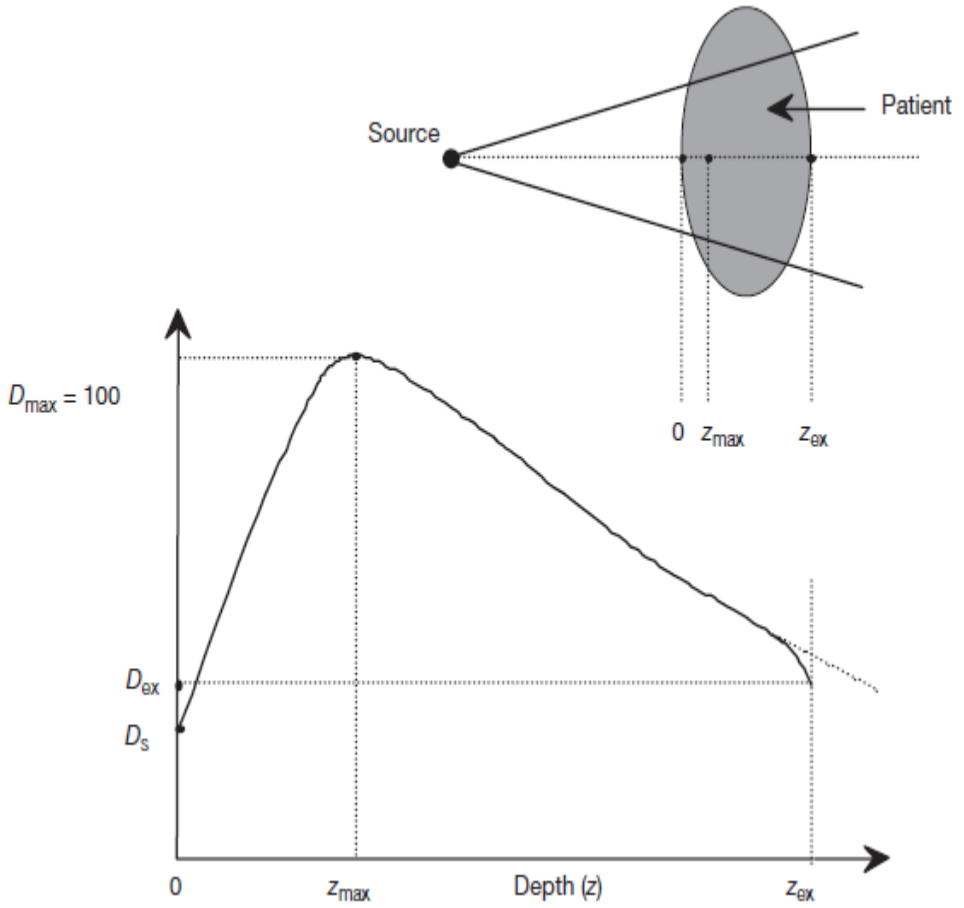
Surface dose

The surface dose represents contributions to the dose from:

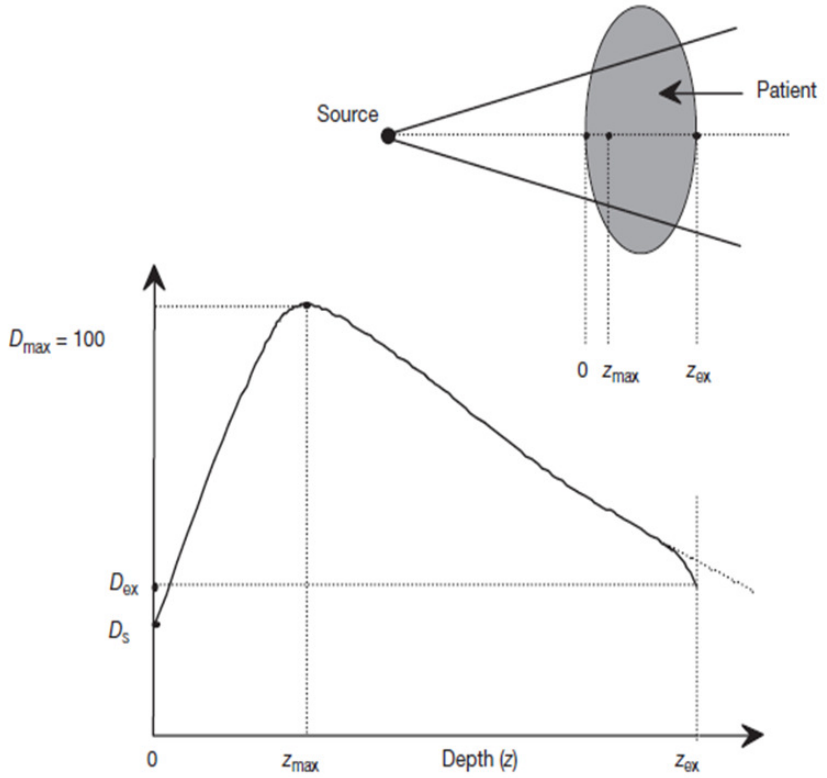
.Photons scattered from the collimators, flattening filter and air;

.Photons backscattered from the patient;

.High energy electrons produced by photon interactions in air and any shielding structures in the vicinity of the patient.



Build-up region



- The dose region between the surface (depth $z = 0$) and depth $z = z_{max}$ in megavoltage photon beams is referred to as the dose buildup region and results from the relatively long range of energetic secondary charged particles (electrons and positrons) that first are released in the patient by photon interactions

Percentage depth dose

In Radiotherapy, a **percentage depth dose curve** (PDD) (sometimes *percent* depth dose curve) relates the absorbed dose deposited by a radiation beam into a medium as it varies with depth along the axis of the beam. The dose values are divided by the maximum dose, referred to as z_{max}, yielding a plot in terms of percentage of the maximum dose.

Beam flatness

The beam flatness F is assessed by finding the maximum D_{max} and minimum D_{min} dose point values on the beam profile within the central 80% of the bea sing the relationship:

$$F = 100 \times \frac{D_{max} - D_{min}}{D_{max} + D_{min}}$$

The overflattening and under-flattening of the beam profiles is caused by the lower beam effective energies in off-axis directions compared with those in the central axis direction.

Beam symmetry

- The beam symmetry S is usually determined at z_{max}, which represents the most sensitive depth for assessment of this beam uniformity parameter.

$$S = 100 \times \frac{\text{area}_{\text{left}} - \text{area}_{\text{right}}}{\text{area}_{\text{left}} + \text{area}_{\text{right}}}$$

$$D_{kor} = \frac{k \times D_{int}}{\%DD} \quad (1.9)$$

$$\varepsilon = \frac{D_{kor}}{D_{ref}} \times 100 \quad (1.10)$$

$E = 6$ MV	$k = 1.0895$	$\%DD = 0.671$	$k/\%DD = 1.624$	$D_{ref}(cGy) = 200$

D_{int}(cGy)	D_{kor}(cGy)	ε(%)	+/−
121.4	197.15	-1.4	+
121.7	197.64	-1.2	+

$E = 18$ MV	$k = 1.0657$	$\%DD = 0.777$	$k/\%DD = 1.372$	$D_{ref}(cGy) = 200$

D_{int}(cGy)	D_{kor}(cGy)	ε(%)	+/−
143.0	196.2	-1.9	+
144.7	198.5	-0.7	+
144.6	198.4	-0.8	+
144.4	198.1	-0.9	+

Quality Assurance Test

THANK YOU FOR ATTENTION!

Introduction

- Nuclear Magnetic Resonance is a technique for probing atoms and molecules based upon their interaction with an external magnetic field.

- The power in the approach lies both in its nondestructive nature and in its sensitivity to the molecular environment of an individual atom.

1945. - Purcell, Torrey and Pound detected weak radio-frequency signals generated by the nuclei of atoms in about 1 kg of paraffin wax placed in a magnetic field.

Simultaneously, Bloch,Hansen and Packard independently observed radio signals from atomic nuclei in water in a magnetic field.

1952. - Nobel Prize in Physics to Purcell and Bloch.

1991. - Nobel Prize in Chemistry to R. R. Ernst (ETH) for FT and 2D NMR.

2002. - Nobel Prize in Chemistry to K. Wuthrich

2003. - Nobel Prize in Medicine to P. C. Lauterbur and P. Mansfield for MRI.

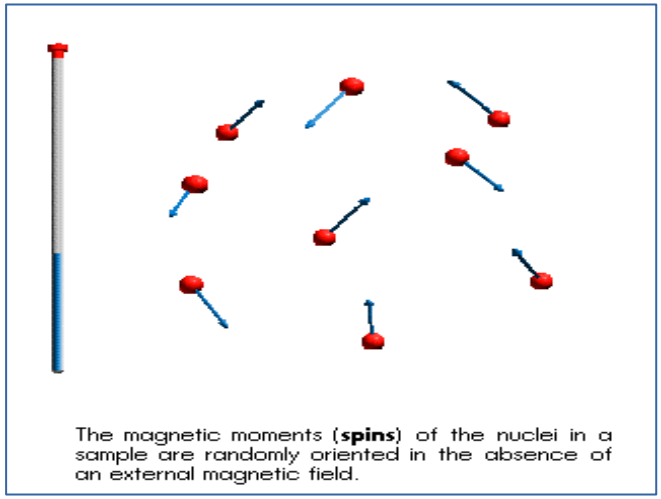
Some Nobel Prizes for NMR

Basic NMR Theory

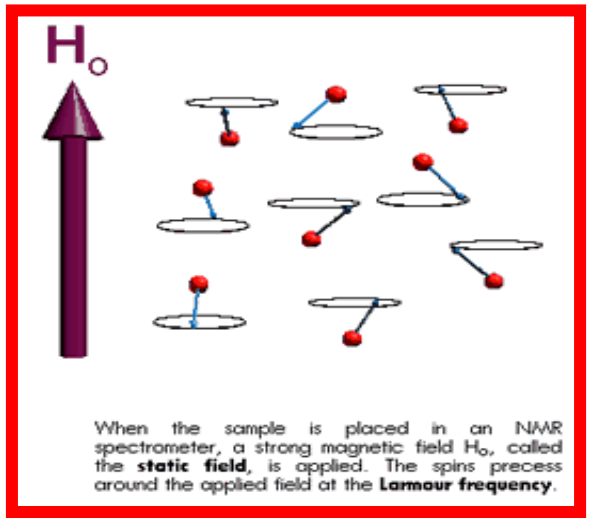
- The theory behind NMR comes from the spin of nucleus and it generates a magnetic field.

- Without an external applied magnetic field, the nuclear spins are random in directions.

- When an external magnetic field is present the nuclei align themselves either with or against the field of the external magnet.

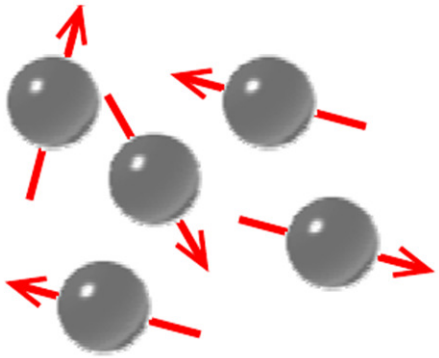


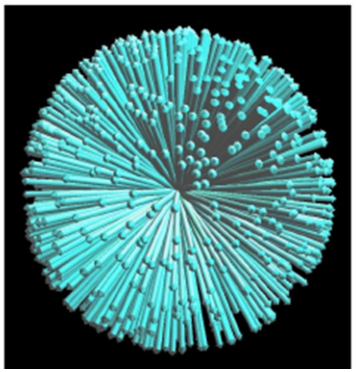
The magnetic moments (**spins**) of the nuclei in a sample are randomly oriented in the absence of an external magnetic field.



When the sample is placed in an NMR spectrometer, a strong magnetic field H_o, called the **static field**, is applied. The spins precess around the applied field at the **Larmour frequency**.

- Each atomic nucleus of hydrogen (a proton) behaves like a small magnet with a north and a south pole.
- Protons tend to align along the direction of an applied magnetic field.
- As long as the magnetic dipole oscillates, it will emit radio waves.





The magnetization of a magnetized sample can be pushed away from equilibrium even by weak radio waves, if these are applied at the resonance frequency.

Afterwards when the external radio wave source is turned off, radio waves will be emitted from the sample as long as the oscillation is ongoing.

This is the NMR signal that is proportional to the amplitude of the oscillation.

The emitted radio waves, for example, are circularly polarized due to the precession.

The proton precession frequency depends only on the field.

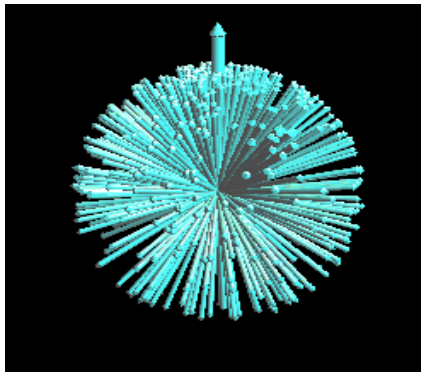
Generally, a magnetic field makes the near-spherical spin distribution rotate around the direction of the field.

Hence, a static field makes it rotate around a fixed axis.

Circularly polarized radio wave field is characterized by a field vector that is orthogonal to the static field.

The spins will precess around this rotating field vector.

•The animation below illustrates how a radio wave pulse can rotate the spin-distribution if it is applied at the Larmor frequency.



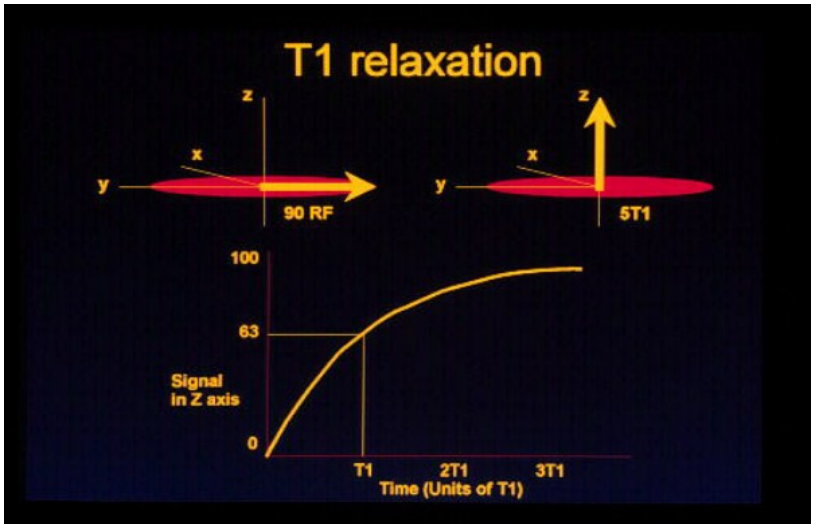
•A resonant field can make the magnetization perform a full 360-degree rotation as shown in the animation, but normally smaller flip angles are used, e.g. 90 or 180 degrees.

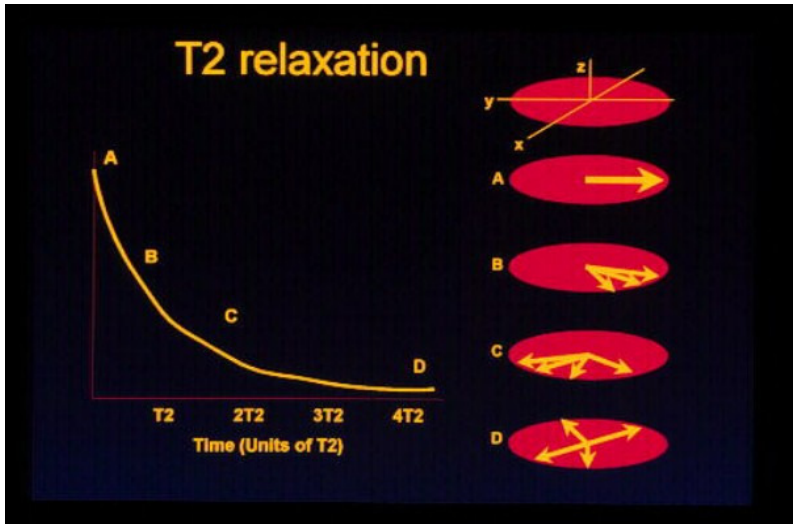
- In addition to the externally applied fields, each nucleus experiences fluctuating magnetic fields (i.e. radio waves) generated by other nuclei that it happens to meet.

- Each of two neighboring nuclei will precess in the static field and in the field generated by the other (spin-spin interaction), but this process cannot change the total longitudinal magnetization since energy is preserved.

•Only when the environment (lattice) acts as a reservoir or supply of energy, can magnetic interactions change the longitudinal magnetization. Therefore T2- and T1-relaxation are sometimes called spin-spin and spin-lattice relaxation, respectively.

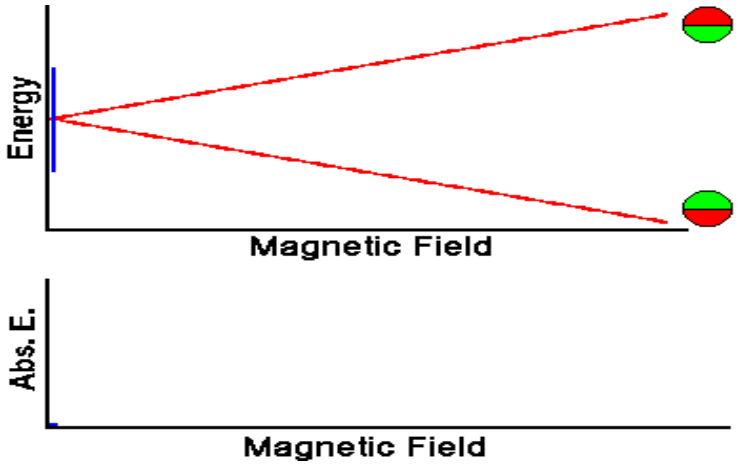
•Since all interactions cause T2-relaxation but only a subset cause T1-relaxation, T2 is always shorter than, or equal to, T1.

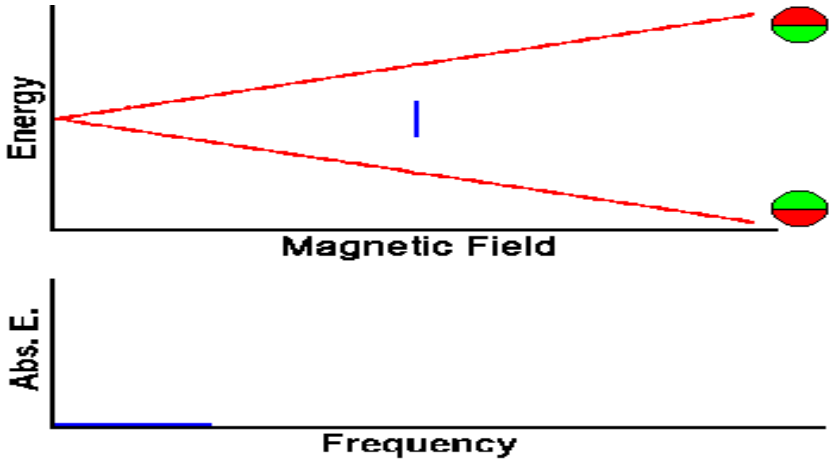




CW NMR Experiment

The simplest NMR experiment is the continuous wave (CW) experiment. There are two ways of performing this experiment. In the first, a constant frequency, which is continuously on, probes the energy levels while the magnetic field is varied. The energy of this frequency is represented by the blue line in the energy level diagram.





The CW experiment can also be performed with a constant magnetic field and a frequency which is varied. The magnitude of the constant magnetic field is represented by the position of the vertical blue line in the energy level diagram.

Uses of NMR

- Chemical analysis: molecular structures and dynamics
- Materials science: characterization of physical properties of matter
- Medical imaging: magnetic resonance tomography (largest area of application)
- Chemical engineering: measurements of diffusion, flow profiles and distributions of velocities
- Well logging in geophysics and oil exploration: characterization of carbohydrates in rocks
- Process- and quality control by low-field NMR and by unilateral NMR Sensors

Equipment for NMR

- Spectroscopy: NMR spectrometer consisting of a magnet, a radio-frequency transmitter, a receiver, and a computer.

- Imaging: NMR tomograph consisting of a magnet, a radio-frequency transmitter, receiver, a modulator for magnetic gradient fields, and a computer.

- Measurements of transport parameters: NMR tomograph.

- Well logging: NMR spectrometer incl. magnet in a tube, shock resistant, and temperature resistant up to 170q C.

- Process and quality control: PC spectrometer or mobile.

- NMR spectrometer with dedicated NMR sensors.