Technical equipment

a) Magnetic shielding:

- In 2004 the actively and passively shielded room BMSR-2 was put into operation with seven Mu-metal layers and additional RF and eddy current shielding, as well as six compensation coil systems. It has set the world record in magnetic shielding (shielding factor 10^7 at f > 0.01 Hz)
- In 2011, a 3 layer shielded room (Zuse-MSR) was assembled providing a residual static field of < 2nT
- Since 2000 a 3 layer shielded room (Acoustically shielded MSR) with additional acoustic damping houses a commercial 128-channel whole head SQUID MEG system.
- Warm bore superconducting shields of 20 mm and 110 mm diameter (see b))

b) SQUID systems

- 304 SQUID vector-magnetometer system developed by PTB. In addition, up to 64 electrical channels can be employed for simultaneous EEG mapping. This system has a frequency bandwidth from DC-10 kHz and a noise of about 2.3 fT/√Hz at 1 kHz. It has a distance between lowest SQUID sensor plane and the sample/head of volunteer of about 25 mm.
- 128-channel SQUID MEG whole head system (Eagle Technologies, Japan) is installed inside the Acoustic MSR having a frequency range from DC – 1 kHz and a white noise of about 3 fT/√Hz at 1 kHz.
- CUBE-II for characterization of magnetically shielded rooms
- 18-channel robust multi-purpose SQUID device. 16 pickup coils (17.1 mm diameter) form a regular grid with channels sensitive to all three spatial directions. Two large hexagonal pickup coils with 74.5 mm effective diameter surrounding the grid at two different heights are designed for the detection of deep sources. The sensors are robust against the application of up to 50 mT polarizing fields allowing their use for ultra-low field NMR and magnetorelaxometry. The noise level of the small-size magnetometers is between 0.85 fT/√Hz and 1.5 fT/√Hz and well below 1 fT/√Hz for the large ones.
- 6 and 18-channel SQUID systems with integrated superconducting shield (see a)) for imaging of magnetic nanoparticle distributions by magnetorelaxometry. The closest distance between SQUID sensor and sample are about 14 mm and 20 mm, respectively
- Ultra-sensitive single-channel SQUID system for ULF NMR and MEG. This SQUID system is based on a gradiometric pick-up coil inductively coupled to a current-sensor SQUID and has a noise level of 500 aT/√Hz. The minimal distance between the sample and the pick-up loop is about 11 mm. A current limiter allows the usage of polarization fields up to 50 mT.
- 3-channel SQUID system for ULF NMR with a Larmor frequency range from 4 Hz – 8 kHz. It has a distance between the lowest SQUID sensor and the sample of only 7 mm. The white noise level is around 3 fT/√Hz.

c) Devices for magnetic nanoparticle characterization

- Magnetic Property Measurement System (MPMS-XL, Quantum design, San Diego) Common commercial device for characterization of magnetic nanoparticle suspension and powder samples (structural parameters, aggregation and binding behavior) in the frequency range (DC ... 1 kHz), temperature (2 K ... 400 K) and field area (+/- 5 T)
- Magnetic Particle Spectroscopy (MPS-3, Bruker BioSpin) for specific quantification of magnetic nanoparticle suspension or powder samples by non-linear dynamic magnetic susceptibility at 25 kHz with amplitudes up to 25 mT.
- Dynamic Light Scattering (Malvern) to determine hydrodynamic size distribution and zeta-potential of magnetic nanoparticle suspensions
- Magnetorelaxometry Imaging (using the 304, 6 or 18 channel SQUID system). Localization and quantification of magnetic nanoparticle distributions in extended samples up to 50 cm diameter by magnetorelaxometry.
- Spectroscopic magnetorelaxometry (using a single channel SQUID system) to characterize the magnetic relaxation of magnetic nanoparticles after removal of a moderate magnetic field of about 2 mT. From these measurements the energy barrier distribution is obtained and the behavior of magnetic nanoparticles in biological systems like cells, blood, tissue can be analyzed and quantified.
- Asymmetric Flow-Field-Flow Platform (Postnova Analytics) for separation of magnetic nanoparticle systems according to their hydrodynamic diameters and size dependent structure analysis by static and dynamic light scattering, UV and magnetic detectors.
- NMR relaxometry (Bruker minispecs mq20 and mq60) to determine T1- and T2 proton relaxation times. Additionally, a gradient unit can be utilized for 2D imaging to determine the homogeneity of MNP embedded in a matrix.
- Photometry (Phenanthrolin-protocol) to determine the iron concentration or amount of magnetic nanoparticle suspension or powder samples. This value is useful to normalize many of the particle parameters obtained by characterization measurements.