Highlights from the "2nd International Workshop on Magnetic Particle Imaging"

Reported from Jena by Silvio Dutz, 31/3/2012

On March 15th and 16th 2012 the **"2nd International Workshop on Magnetic Particle Imaging"** (www.iwmpi.uni-luebeck.de) was held at the University of Lübeck in Germany. This international meeting was chaired by **Prof. Thorsten M. Buzug** (University of Lübeck) and **Dr. Jörn Borgert** (Philips Research Hamburg). The workshop aimed at covering the status and recent developments of both, the instrumentation and the tracer material used in Magnetic Particle Imaging (MPI), as each of them is equally important.

Fig. 1: Altogether 162 scientists from 12 countries attended the meeting and presented 3 key note lectures, 42 talks, and 26 posters.

MPI is a novel imaging modality which uses various static and oscillating magnetic fields, as well as tracer materials made from iron oxide nanoparticles to perform background-free measurements of the particles local concentration. The method exploits the non-linear re-magnetization behaviour of the particles and has the potential to surpass current methods for the detection of iron oxide in sensitivity and spatio-temporal resolution.

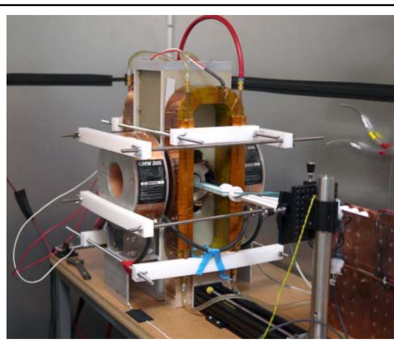

Fig. 2. Ultrafast scanner built by the Conolly group.

In the first section of the talks about MPI instrumentation members of the ***Conolly-Group*** (University of California, Berkeley) presented a new data reconstruction algorithm basing on filtered back-projection which enables fast 3D tomographic imaging of rotating objects. Furthermore they described the design of their new MPI scanner with a higher FOV (suitable for mice and rats: 12 x 5 x 5 cm^3) and a better spatial resolution (about 2 mm) than previous devices which enables a scan of whole mouse within 3 seconds (**Fig. 2**). At the opening of the evening event with dinner in the harbour centre of Lübeck, ***Bernhard Gleich*** (Philips Technologie Hamburg) – one of the two inventors of MPI – gave a keynote lecture about the hardware components of a MPI scanner. He focused on the particular requirements on some electronic parts of the system which can not be fulfilled by standard technologies and showed the aspects of the complete method, the optimization of which will improve the capability of MPI. On the second day his colleague ***Jürgen Rahmer*** reported about the implementation of additional coils which generate focused fields that operate at lower frequencies and extend the accessible imaging range. This demonstrated the possibility of moving the rapidly encoded imaging volume along an arbitrary 3D trajectory. The ***Buzug-Group*** (University of Lübeck) presented their results regarding a new setup for the generation of the field-free point consisting of four coils which considerably reduces the electrical power losses for off-centre field-free point generation. They then presented simulations that highlight the influence of magnetic field optimization on the image quality when using Radon-based reconstruction for field-free line imaging. This increases the sensitivity of the technique as well as the utilized field of view while decreasing reconstruction time. They completed their report with the presentation of an optimized single-sided MPI scanner geometry (**Fig. 3**) which allows the examination of larger objects than in the closed geometry scanners of the first generation.

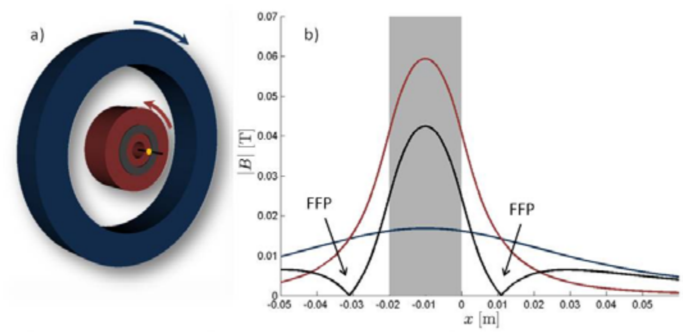

Fig. 3: a) Setup of a single-sided MPI scanner made up of two concentrically positioned transmit coils (red and blue) and a separate receive coil (grey). Resulting magnetic flux density *B(x)* (absolute values) of the selection field along the coil axis. Two FFPs are present, one on each side of the coils of which the position is indicated by the grey background.
[T. Sattel, T. Knopp, S. Biederer, B. Gleich, J. Weizenecker, J. Borgert, T. M. Buzug: Single-Sided Device for Magnetic Particle Imaging, J Phys D: Appl Phys, 2009, 42, 1-5]

Research on the magnetic nanoparticles for the use as MPI tracers revealed that there are two particle types which seem to be promising for application. The first type are larger monosized superparamagnetic particles. ***Kannan Krishnan*** (University of Washington) reported in his keynote lecture about recent progress in his lab on development of such particles. For the investigated size range particles of about 20 nm and a very narrow size distribution showed a 30% better spatial resolution compared to Resovist – which is the best commercially available tracer so far. The presented particles also yield harmonic spectra with greater intensity than Resovist for all of the measured 40 harmonics. ***Aidin Lak*** (University of Braunschweig) prepared particles of comparable size which showed similar MPI performance like Resovist.

On the other hand, particles consisting of clusters of small cores are also promising for use as MPI tracers. A small portion of such clusters was found in Resovist and suspected to be responsible for the good MPI signal of Resovist. This speculation was confirmed by ***Norbert Löwa*** (PTB Berlin) who enriched these clusters by magnetic separation. MPI performance improved by about a factor of two (**Fig. 4**). A detailed investigation of Resovist regarding the correlation of energy barrier distribution and harmonics spectrum was presented by ***Takashi Yoshida*** (Kyushu University). They obtained the best spectra for particles with large magnetic moment but small energy barrier which is typical for such multicore particles.

Beside imaging experiments in the MPI scanner Magnetic Particle Spectroscopy (MPS) is the most common tool to rate the MPI performance of prospective tracer particles. The most groups use spectroscopy devices with one fix excitation frequency of mostly 25 kHz. ***Frank Ludwig*** (University of Braunschweig) introduced a spectroscope which allows tuning the amplitude between 0 and 25 mT as well as a frequency variation from 500 Hz up to 10 kHz. In combination with static magnetisation measurements, AC susceptibility, and magnetorelaxometry, this new instrument enables a much more detailed investigation of the tracer materials.

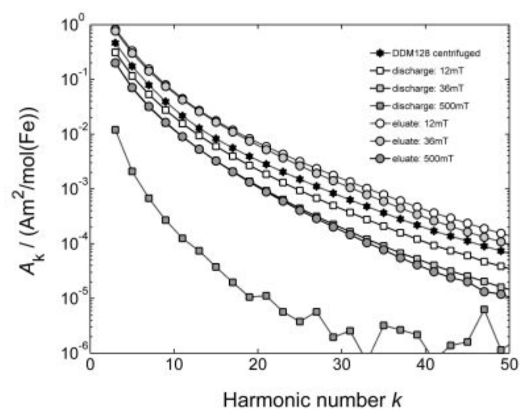

Fig. 4: Odd harmonics of the MPS spectra normalized to iron concentration for Resovist (DDM128) as well as fractionations of this. The clusters in fractions of larger mean particle size (eluate 12 and 36 mT) show best MPI performance. *[N. Löwa, D. Eberbeck, U. Steinhoff, F. Wiekhorst, L.Trahms. Potential of Improving MPI Performance by Magnetic Separation. (Hrsg.: T.M. Buzug und J. Borgert) Magnetic Particle Imaging, Springer Proceedings in Physics 140: 73–78, Springer Verlag, Berlin Heidelberg (2012)]*

Due to forthcoming use of MPI on humans there is an urgent need for research on possible adverse effects of the applied fields on patient's health. Based on simulations, ***Olaf Dössel*** (Karlsruhe Institute of Technology) stated that the stimulation of excitable tissue by MPI drive field is very unlikely for the currently used field parameters. Furthermore the stimulation of nerves is expected mainly on the periphery of the body whereas the tissues of the heart will experience smaller excitation. In human-subject experiments at arm and leg of volunteers ***Emine Saritas*** (University of California, Berkeley) found thresholds for magnetic field amplitude as function of frequency for the occurrence of magnetostimulation. This threshold decreases with increasing frequency and is inversely correlated to the body-part size.

Further sessions covered Magneto-Relaxometry, Magnetic Particle Separation, Magnetic Particle Theory, and Medical Applications of magnetic nanoparticles as well as a poster session with contributions to all mentioned topics. The complete scientific program can be found here:

http://www.iwmpi.uni-luebeck.de/fileadmin/website/2012_2nd_IWMPI/Tentative_Program_IWMPI2012.pdf

Extended proceedings of the workshop are published as book and e-proceedings distributed by Springer:

http://www.springer.com/engineering/biomedical+engineering/book/978-3-642-24132-1

The next MPI-Workshops will take place in Berkeley (2013) and Berlin (2014). Detailed information will be provided well in advance at the homepage of MPI group of Prof. T. Buzug from the University of Lübeck:

http://www.imt.uni-luebeck.de/index.php?id=mpi.