MR-MICROSCOPY ON A HUMAN 7T-SCANNER

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Introduction/Purpose

The spatial resolution in MR-micro-imaging is limited by a number of factors including: B_0 homogeneity, gradient strength, sensitivity of the MR-coils, the gradient amplifier performance in addition to the specific features of the sample. High-field small-bore MR-Scanners allow for the visualization of fine structures below the resolution limit (about 100 µm) of the human eye (MR-microscopy). Such high spatial resolutions can be looked upon as key technological tool in MRI-based molecular imaging in biological models and for human pathology samples as practiced with research-level MRI systems. Is it now possible to achieve similarly high resolution with acceptable Signal-to-Noise-Ratio (SNR) on high field human MR-scanners through application of high gradient strength insert coils and sensitive detectors? The actually achieved spatial resolution might be much lower than the pixel size obtained, due to susceptibility artifacts, linewidth or diffusivity of molecules. Consequently the actual spatial resolution is to be evaluated quantitatively. We wish to demonstrate the evaluation process for high resolution imaging with a newly installed custom designed 90 mm microscopy insert on a horizontal 7T Scanner for human research at high field strength (inner available diameter: 595 mm).

Materials and methods

We installed a micro-gradient insert capable of G = 750 mT/m in the bore of a Siemens Magnetom 7T and connected it to a voltage and current limited whole body gradient amplifier. In addition to custom tuning of the matching characteristics of the amplifiers, a set of three 100 µH high power inductors, wound on toroidal cores, were applied in series, to bring the coil impedance closer to the requirements of the amplifiers. In addition the in-line inductors served as voltage limiters during the pulsed operation. A small sized resonator (1H: ν = 297,2 MHz) was used for sensitivity reasons (inner diameter: d_i =19 mm). The spatial resolution was checked using a specially designed set of spatial grids, which feature periodically arranged slits at spatial periods between 2048 and 64 µm. The smallest slits thus present a lateral structure at 34 µm width. The grids were manufactured using micro-lithography on a silicon wafer. The whole set of grids was positioned in a reference phantom filled with a solution of copper sulfate. The MR-microscopy protocol is based on a Multi-slice (slnr: 5) Turbo-spin echo (TSE) sequence (TE: 9.5 ms; TR: 800 ms; av: 32; Mtx: 232 x 512; bw: 295 Hz/pixel; measurement time Tm: 21 min).

Results

MR-microscopic images (Voxel size: 50.9 x 25.4 x 200 µm^3) are obtained (Fig. 2) within 20 min measurement time at good Signal to Noise Ratio (SNR = 6.43). The region around the finest grid sets at bottom is enlarged and shown in fig. 3a) after rotation. All of the grid sets are spatially resolved. Even the 34 µm slits separated by 30 µm wide silicon bars are visualized. The spatial separation is confirmed by investigating the profiles crossing the grid sets (fig. 3b). Note also the slight bowing of the bar images most likely due to susceptibility differences present between silicon and the copper sulfate solution.

Conclusion

A micro-imaging system based on a human MR-scanner can be configured using customized hardware, especially a strong gradient system and a sensitive detector coil. Very high resolution, MR-microscopy level images can be obtained using small voxel sizes at sufficient SNR. The size of the sample is mainly limited by the diameter of the resonator. We demonstrated the microscopic spatial resolution using micro-lithographically generated grids on a silicon wafer. Therefore we show that MR microscopy is possible on a whole body MR System, and hope that this demonstration will stimulate new applications for micro-pathology in medicine.

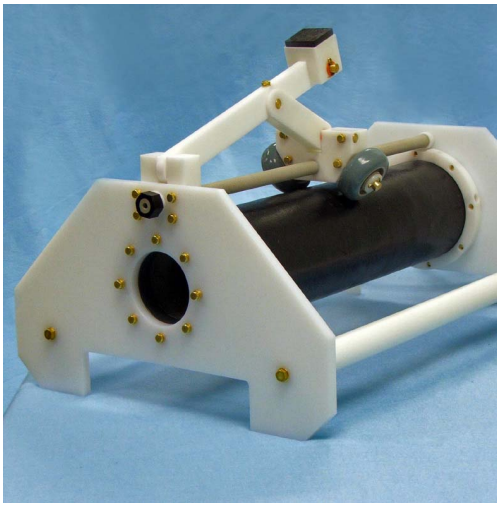

Fig. 1 *Gradient insert for MR-microscopy (G = 750 mT/m, inner available diameter: 90 mm). For mechanical fixation an additional adjustable swivel arm is pressed against the inner wall of the bore.*

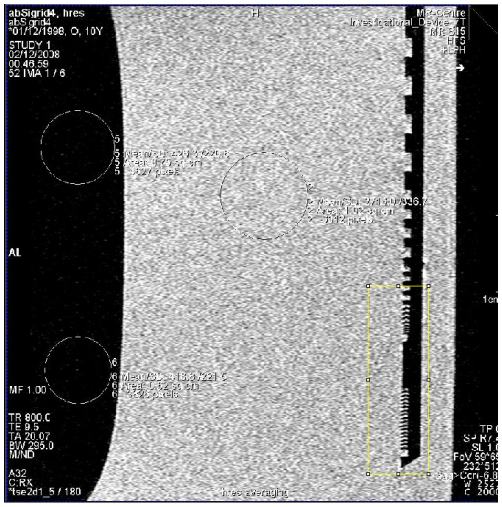

Fig. 2 *MR-microscopic image of the silicon grid sets. The slits range from 512 µm at top (256, 128, 64) down to about 34 µm (period: 64 µm). Regions of interest (ROI) for calculation of the SNR are indicated (circles): Also the trace (yellow rectangle) of the enlargement (fig. 3a top) is shown.*

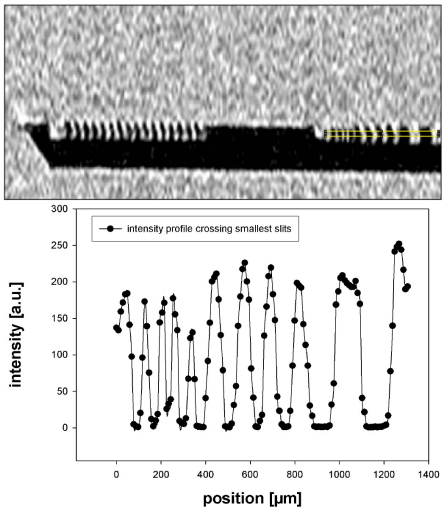

Fig. 3a top *The region around the finest grid sets at bottom of Fig. 2 (yellow rectangle) is enlarged and rotated. The profile path for obtaining the modulation depth (fig 3b) is indicated.*
Fig. 3b bottom: *The profile originating from the path indicated (yellow lines) in fig 3a is plotted. Note the deep modulation even for the smallest slits at 34 µm groove width.*

Final remarks

The concepts and information presented in this paper are based on research and are not commercially available.

References

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