Towards MRI Measurement of Magnetic Particle Spacing at Micron Dimensions

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Introduction. Using an array of microfabricated magnetic particles, we explore the ability of MRI to determine the spacing between two such objects at high spatial resolution. This is an analogy to optical microscopy that can detect point sources at much higher than diffraction limited resolution (1). It was reasoned that increasing the resolution preferentially along the direction of the spacing would enable detection and characterization of dipolar patterns at high resolution without decreasing the overall voxel volume enabling maintenance of SNR. The goal is to precisely measure the distance two labeled biological cells as they interact.

Methods. An array of nickel particles was microfabricated (2) on a 15-mm glass slide with spacings from 5 µm up to 250 µm (Fig 1). The particles are disc shaped with 2 µm diameter and 200 nm thick. The slide was then placed in a custom made holder which allowed for a 100µm layer of water to be next to the slide. Vacuum grease was sufficient to hold the slide and water without leaking. The holder was then placed into a 20 mm birdcage coil (m2m Imaging, Ohio, USA) for imaging. Gradient-echo MR images were acquired on a 14T scanner equipped with a Bruker Avance III console. Image parameters were set such that the readout dimension was set along direction of the particle spacing, and at a higher resolution. The parameters were: TR/TE = 200/7 ms, matrix size = 1024 x 256, fov = 19.2 mm, giving a nominal pixel resolution of 18.75 x 75 µm. Images were reconstructed as both magnitude and phase images.

Results. Figure 2A shows a magnitude image of the particle array and a phase image is shown in 2B. In this example the readout direction is transverse to the B_0 field. Results from the phase map are the most promising and line plots through particles spaced at 5, 20 and 40 µm are shown in figure 3. The most interesting point is in the center of the line plots, which changes rapidly with separation. This is plotted in Figure 4 for more particle pairs, and shows that it maybe possible to determine the separation to level of a pixel in this case.

Conclusion. We have demonstrated a method evaluate particle spacing at high resolution. Simulation of the entire spatial pattern should enable much higher accuracy. In addition, methods can be developed to measure spacing in arbitrary directions. Finally, microfabrication allows us to study magnetic particles systems with very high spatial precision.

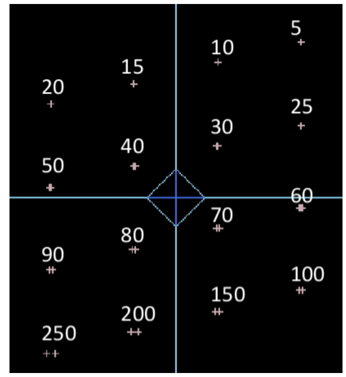

Figure 1. Particle spacing layout for microfabrication. Distances are in microns.

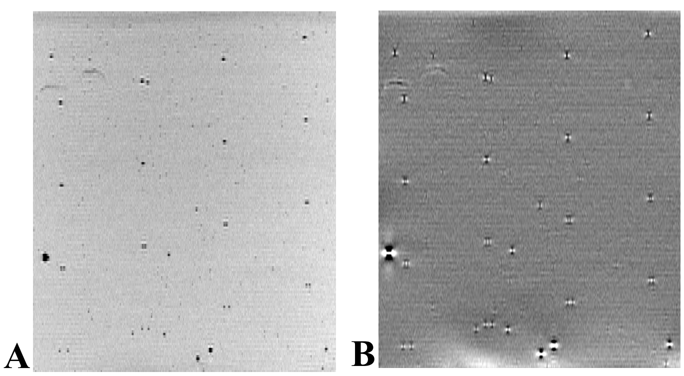

Figure 2 A Gradient-echo magnitude image from particle array and **B** phase image. The readout dimension is left to right and has 4x higher resolution (18.75 µm). The B_0 field runs top to bottom in this image.

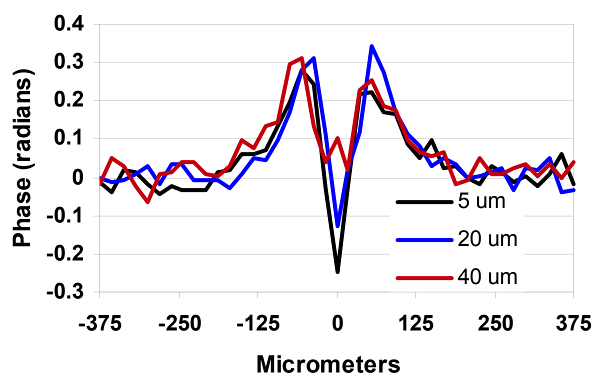

Figure 3. Line plots from the phase image through particles at spacing levels of 5, 20 and 40 microns. It is noted that the center point changes rapidly with the spacing.

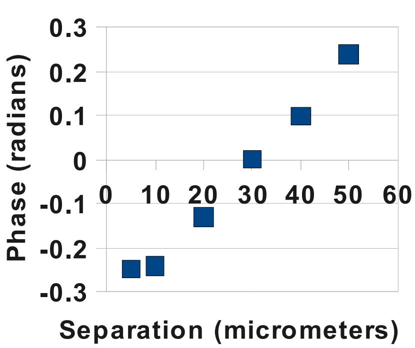

Figure 4. Plot of the phase of the center point as particle spacing is increased from 5 to 50 µm.

References

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Acknowledgments. Thanks to the Mouse Imaging Facility, Intramural Program, NINDS, NIH for use of the 14T and to NIST at Boulder, CO for use of the cleanroom facility.