3D Magnetic Particle Imaging with a Traveling Wave

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Introduction

Magnetic **P**article **I**maging is a new imaging method based on the nonlinear response of ferro- and superparamagnetic particles to magnetic fields [1]. For imaging, a field free point (FFP) of a strong magnetic gradient on the order of 1-5 T/m is moved through the sample. A new approach for gradient design was presented for performing dynamic imaging in a linear sampling scheme by using a traveling wave [3]. Based on this concept we present an extension for doing 3D imaging using a traveling wave in combination with frequency mixing [3] and a sliced field of view (FoV). This approach allows to arbitrarily increase the FoV in one direction with the possibility of spatial encoding in the additional 2 dimensions.

Method

The dynamic linear gradient array (dLGA) consists of 16 consecutive simple coils (full length: 144 mm) for generating two FFPs (gradient strength: z-axis: 3.5 T/m, x and y-axis: 1.75 T/m, 1.6 kW). Applying a sinusoidal current (f_1=1 kHz) with an increasing phase shift to adjacent coils the FFPs travel along the axis in z-direction. Two perpendicular pairs of saddle coils were oriented orthogonally to the dLGA. The first pair is for the frequency mixing. It generates a sufficient high field strength (10-15 mT at f_2=24 kHz, 200 W) to move the traveling FFPs about 10 mm out of the symmetry axis (z-axis) in a slice. The second pair provides the third encoding direction by shifting the 2D FoV slices gradually. The field strength of the second coil pair can be adjusted up to 10-15 mT (200 W) and can move the 2D imaging plane in the y-axis (see Fig. 1). All coils are driven using common audio amplifiers (TSA4-700 and TA2400 MK-X, t.amp).

Results

In preliminary tests the simulation results of the 2D point spread function (PSF) were confirmed for different slices. In addition, the spatial resolution was determined to be less than 2 mm in z-direction and less than 3 mm in x- and y-direction. Figure 1.D shows the 2D reconstruction corresponding to a test sample.

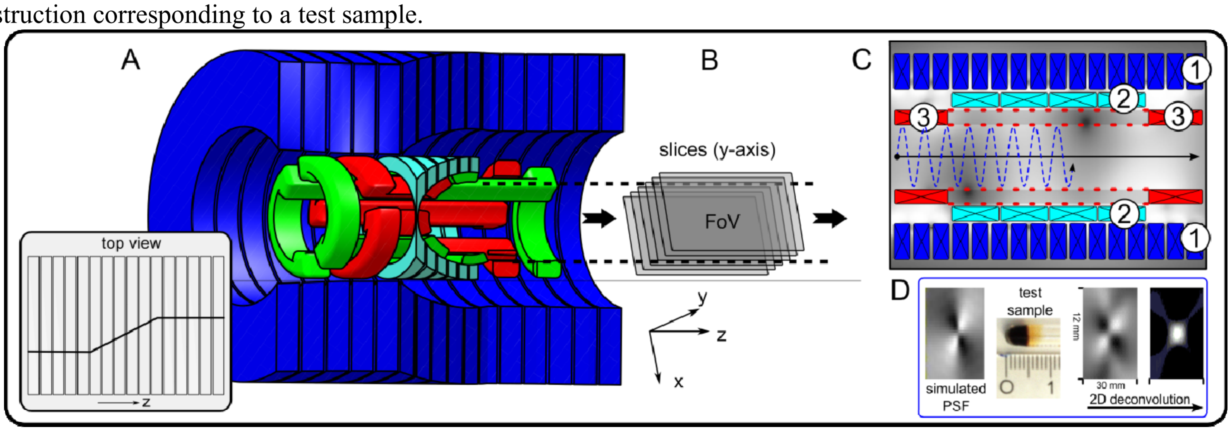

Fig. 1: *Sketch of the 3D-MPI-scanner:* ***A****: profile section of the 3D scanner:* ***Blue*** *(1): gradient coils of the dynamic linear gradient array (dLGA) for generating the traveling FFPs (1D – z-axis).* ***Red*** *(3): Helmholtz coil pair in saddle-coil configuration for frequency mixing (2D – x-axis).* ***Green****: Helmholtz coil pair (orthogonal to the first coil pair) for slicing the FoV (3D – y-axis).* ***Cyan*** *(2): Receiving coils array parallel to the dLGA.* ***B****: slices parallel to the z-x-plane build the FoV.* ***C****: single slice: the two FFPs (dark regions) travel along the dashed path.* ***D****: comparison between the simulated and the measured 2D PSF for a delta like sample.*

Conclusion

With the traveling wave approach it's possible to increase the FoV along the symmetry axis (z-axis) without increasing the acquisition time while keeping the specific absorption rate constant. Frequency mixing increases the SNR by reducing the fractional bandwidth and shifting the signal to higher frequencies for a better signal. The acquisition time is about 1 ms per slice. For a 3D volume with 20 mm in height the encoding time increases to 20 ms for a resolution of about 1 mm in y-direction.

References

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