Low-Frequency Broadband Actuator for MRE

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INTRODUCTION

Low frequency elastography is important for deducing material properties of tissue whose characteristic time scales are much longer than the frequencies typically probed in MRE, including viscoelastic and poroelastic properties. Low frequency MRE is however challenging due to the large and stable displacements required to match the NMR sensitivity obtained at high frequencies (i.e., velocity measured with PFG-NMR = displacement × frequency). In this study, we report the development of a new low-frequency broadband (0 – several kHz) actuator to perform MRE within a micro-imaging MRI scanner.

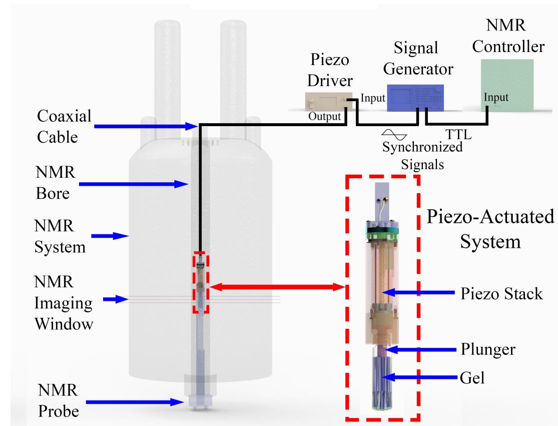

Figure 1. Schematic of the new piezo actuator for low frequency MRE in a vertical bore magnet.

METHODS

Our sample consists of two layers of agarose gel of 0.1% and 0.12% concentration stacked on top of each other in a glass tube. The actuator consists of a piezoelectric stack operable from 0 to 5 kHz (Thorlabs, Sterling, VA) with a stroke length equal to 100 µm, which is interfaced to a 3D printed plunger which rests on top of the gel (Figure 1). The piezo is driven by a 150 V driver which is synchronized with the NMR system and run at 10 Hz for this study.

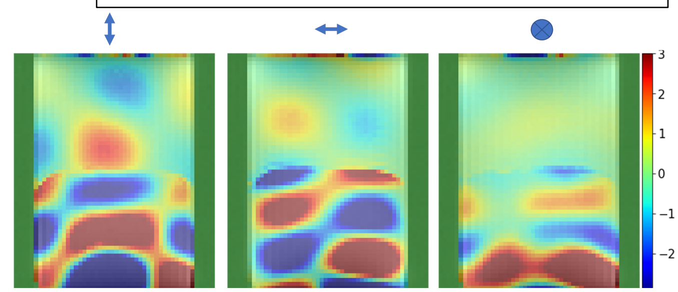

Figure 2. The components of the real part of the measured displacement vector field (µm) filtered at 10 Hz. The direction of the components is indicated using arrows.

The longitudinal motion of the plunger introduces shear waves in the gel which was captured using a pulsed gradient spin echo (PGSE) experiment triggered at different phases of the actuation cycle spaced 10 ms apart for one full cycle. 3D MRE data was acquired on a 7T system (Bruker Biospin) using 25 mm quadrature RF probe with the following parameters: $\delta/\Delta = 1.5/10$ ms (Hadamard scheme with b = 0, 250 s/mm^2), FOV=30 x 25 x 25 mm, TR/TE = 200/16 ms, and a 0.5 mm isotropic voxel resolution. The shear modulus of the gel was estimated using algebraic Helmholtz inversion.

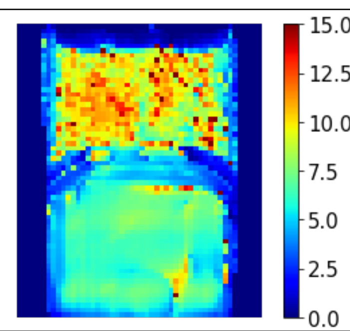

Figure 3. Reconstructed shear modulus (Pa) of the agarose bilayer phantom (0.1% bottom, 0.12% top).

RESULTS AND DISCUSSION

The real part of measured displacement field filtered at 10 Hz is given in Figure 2, which shows uniform mechanical excitation of the FOV studied. The estimated shear modulus map is shown in Figure 3, which clearly distinguishes the layers having two different gel concentrations based on their differences in stiffness (6 vs 10 Pa on average).

CONCLUSION

We have developed a new MRE actuator to study low frequency mechanical properties of soft materials. The wide range of frequencies achievable with the new actuator could help develop and validate new MRE methods.