2D Imaging without Gradient Coils in a Low-Field Spokes-and-Hub Permanent Magnet

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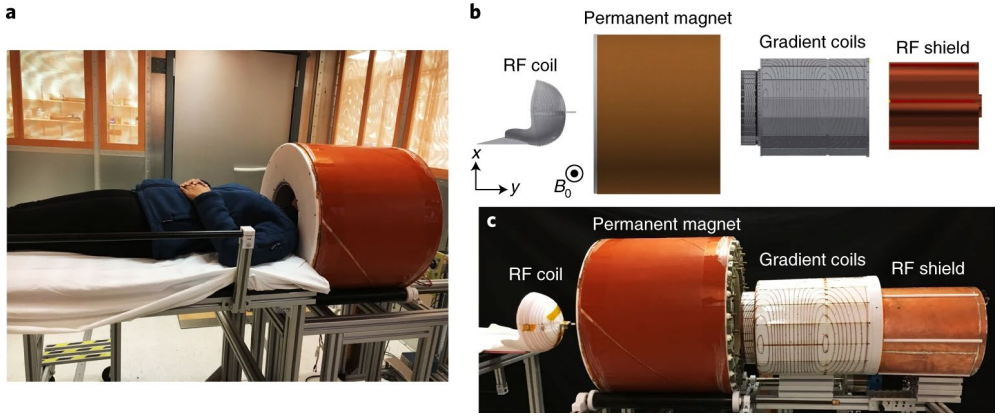
Declaration of Financial Interests or Relationships

Speaker Name: Irene Kuang

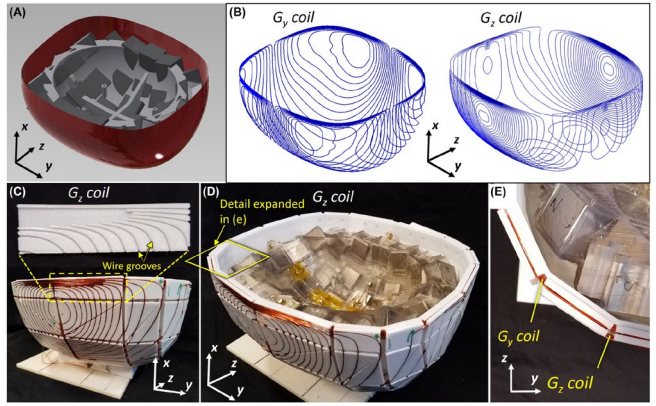
I have no financial interests or relationships to disclose with regard to the subject matter of this presentation.

Permanent Magnet Imaging

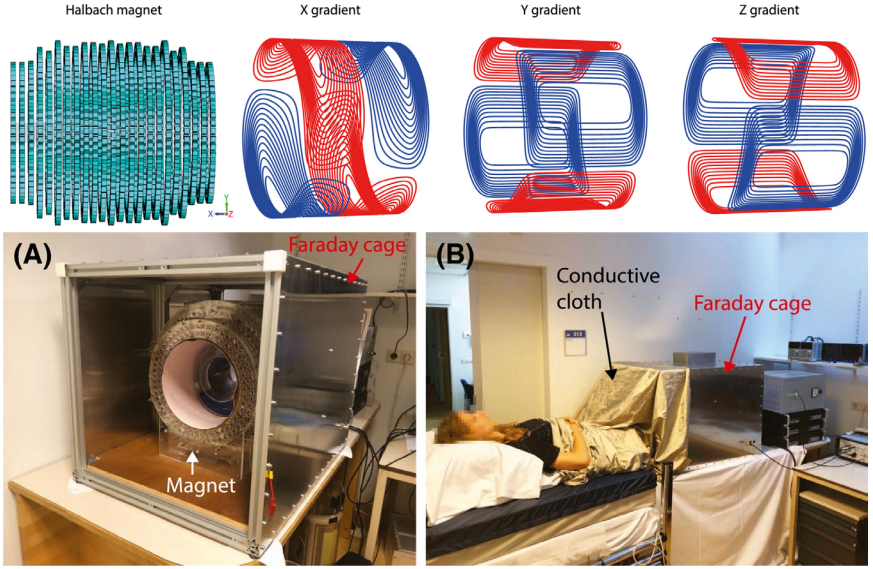
- ✓Low cost
- ✓Portable
- ✓Safe for point-of-care and classroom use
- —Inhomogeneous compared to clinical scanners
- —Gradient non-linearity across FOV



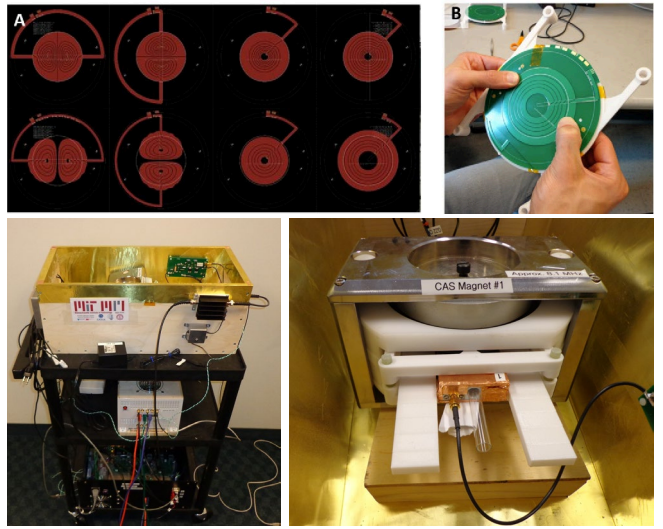
Cooley et al., *A portable scanner for magnetic resonance imaging of the brain*. Nat. Biomed. Eng., 2021.



McDaniel et al., *The MR Cap: A single-sided MRI system designed for potential point-of-care limited field-of-view brain imaging*. Magn. Res. Med., 2019.

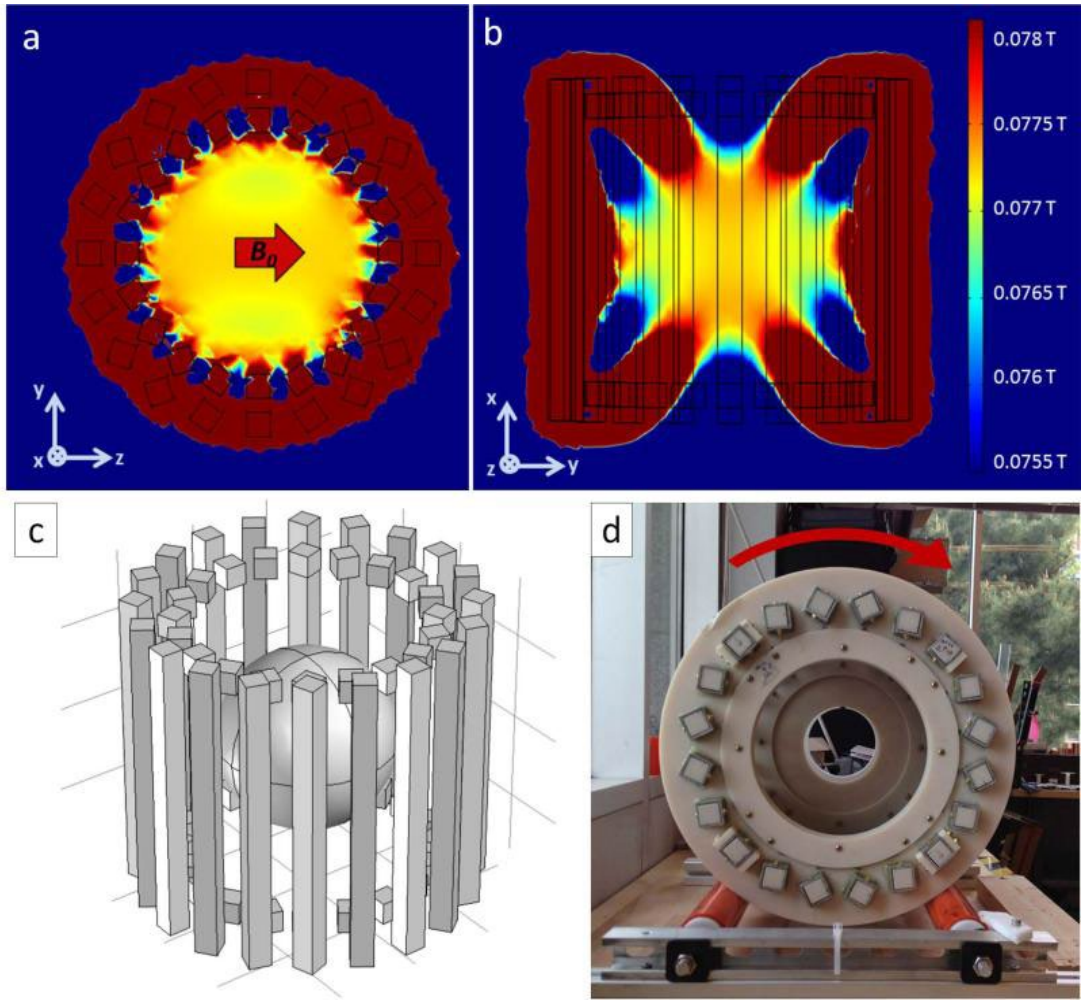


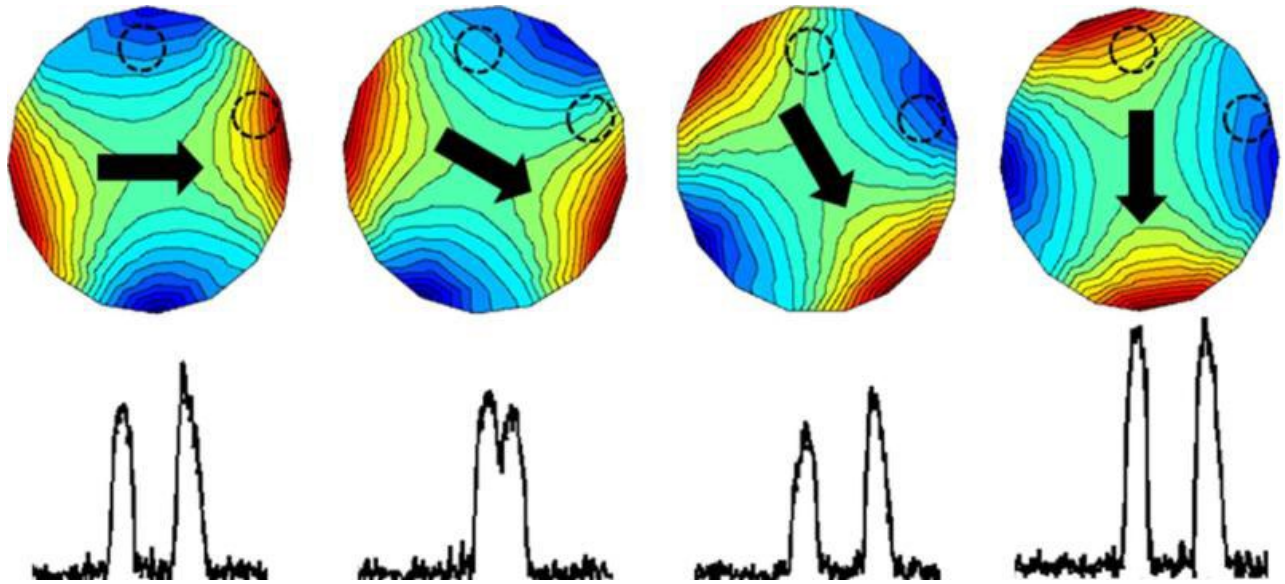
O'Reilly et al., *In vivo 3D brain and extremity MRI at 50 mT using a permanent magnet Halbach array*. Magn. Res. Med., 2020.



Cooley et al., *Design and implementation of a low-cost, tabletop MRI scanner for education and research prototyping*. J. Magn. Res. Imaging, 2019.

Mechanically-Generated Gradients for Imaging

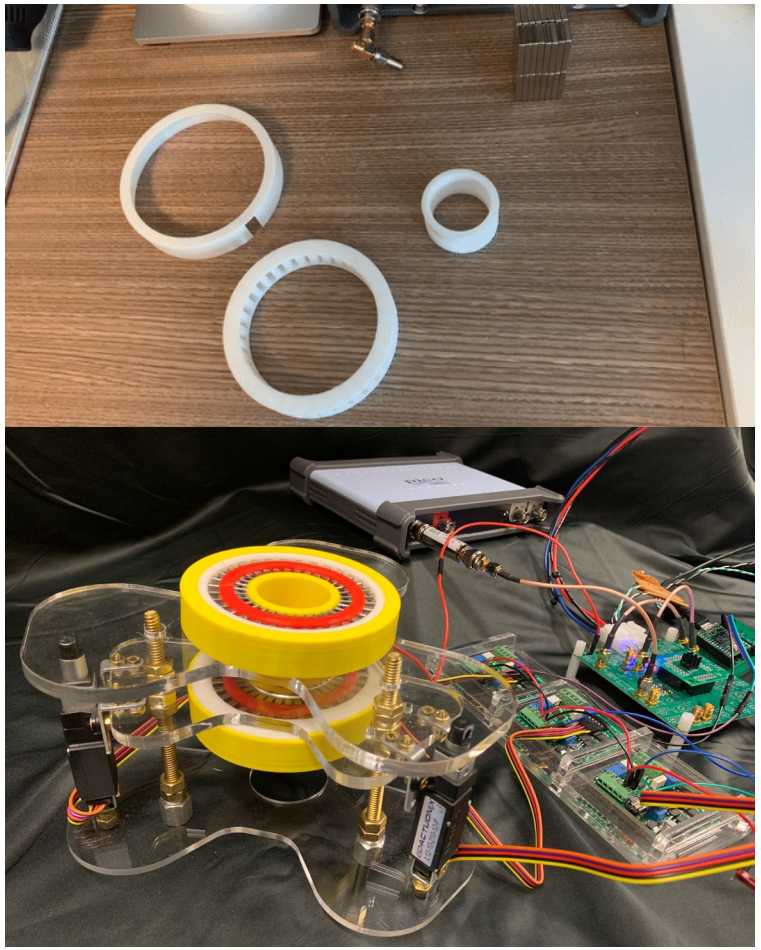




projections acquired from rotating Halbach magnet

Cooley et al., *Two-Dimensional Imaging in a Lightweight Portable MRI Scanner without Gradient Coils*. Magn. Res. Med., 2015.

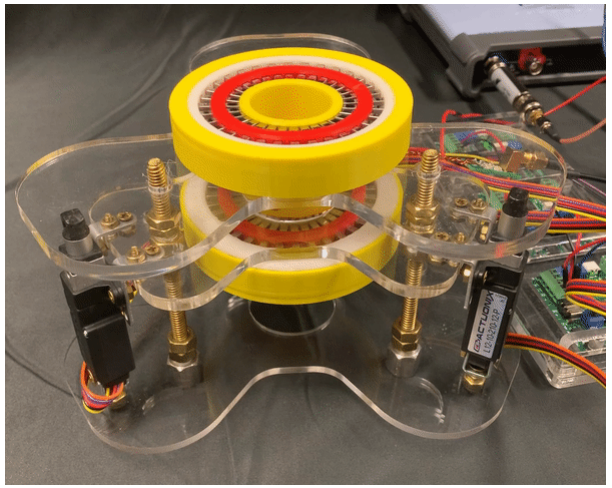
Hand-Held ‘Spokes-and-Hub’ Magnets

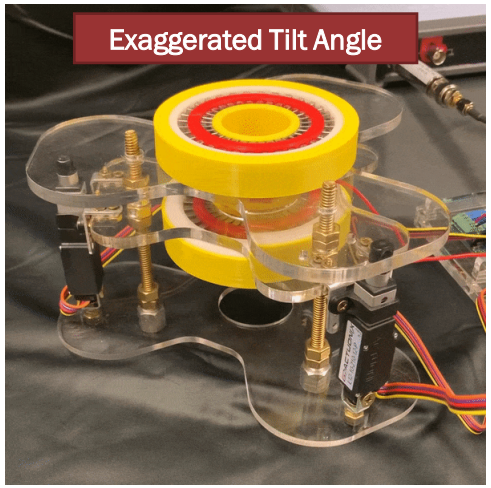


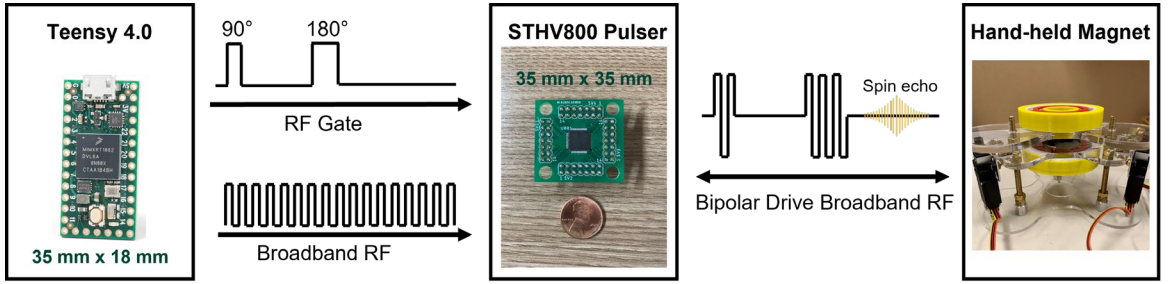
- ✓ Easy & safe to assemble
- ✓ Low cost (<200 USD)
- ✓ Commercially-available parts

Aubert, G., U.S. Patent No. 5014032, 1991.
Kuang et al., Int. Soc. Magn. Res. Med., 2019.
Kuang et al., Int. Soc. Magn. Res. Med., 2020.

Hand-Held ‘Spokes-and-Hub’ Magnets







20 USD

8-channel Ultrasound Pulser
STHV800: 30 USD

200 USD

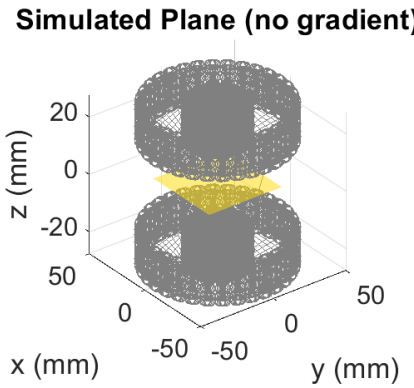
Aubert, G., U.S. Patent No. 5014032, 1991.
Kuang et al., Int. Soc. Magn. Res. Med., 2019.
Kuang et al., Int. Soc. Magn. Res. Med., 2020.

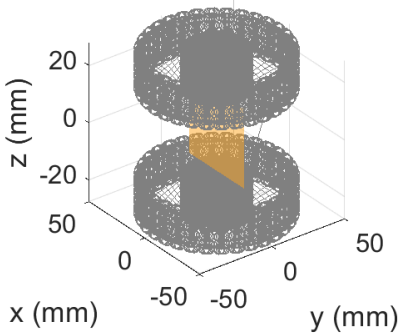
Simulated Field Maps

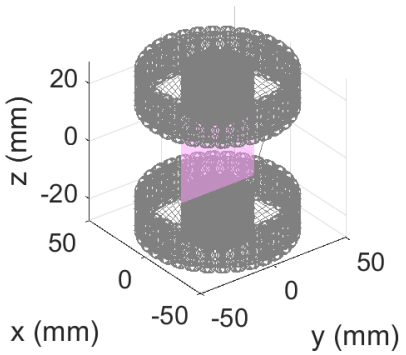
B_0 = 192 mT

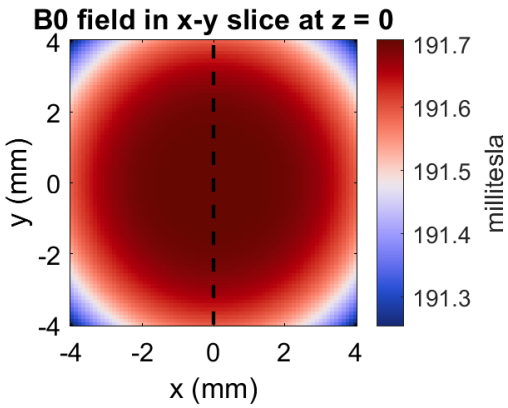
f_0 = 8.18 MHz

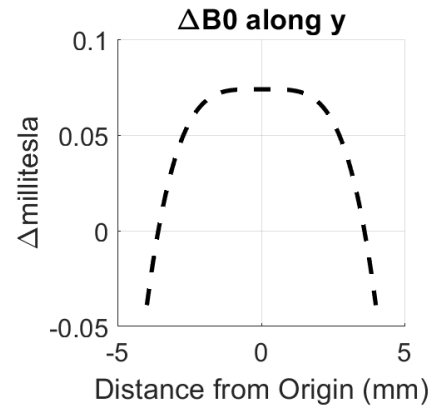
(2000 ppm)

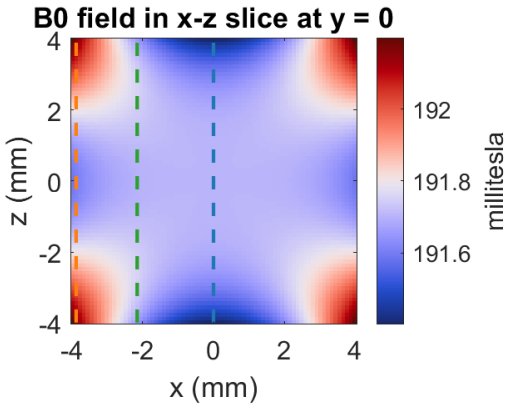


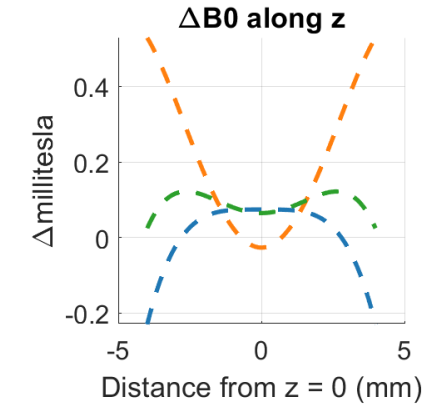


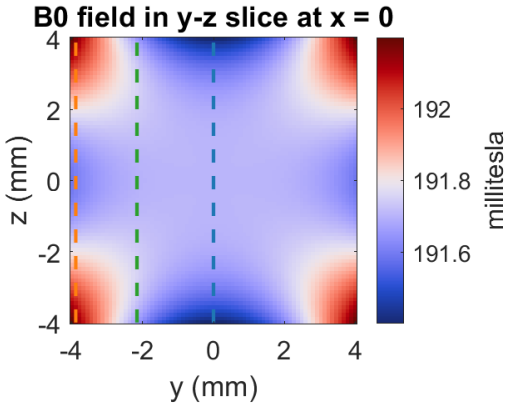


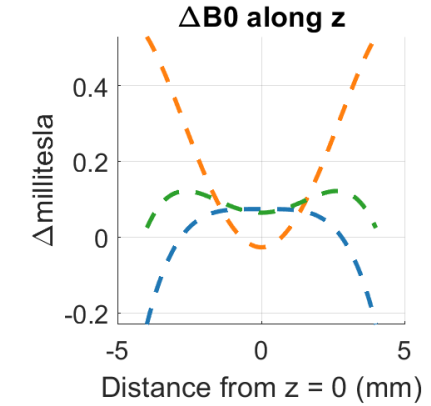




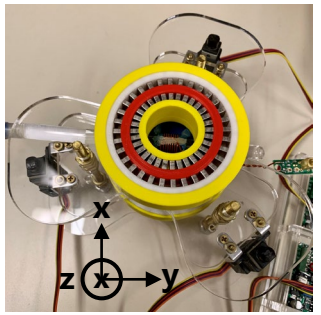


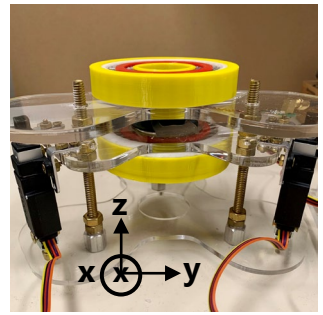


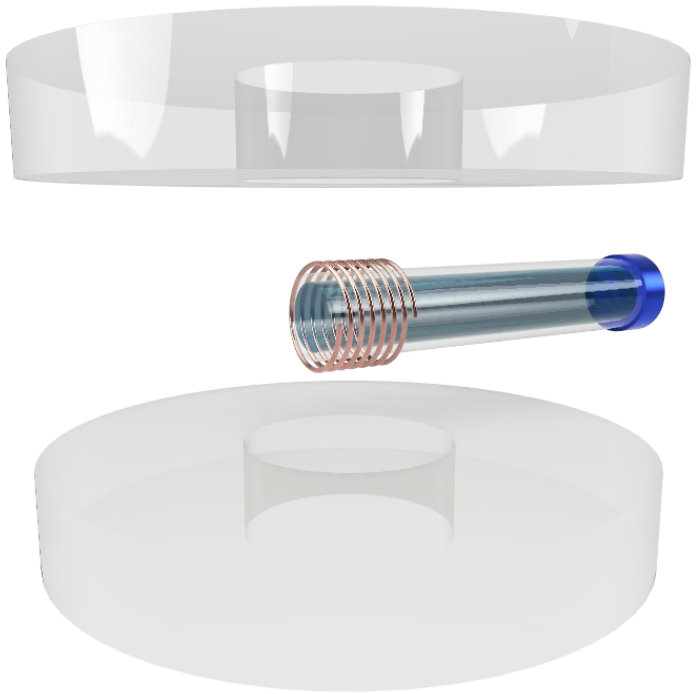


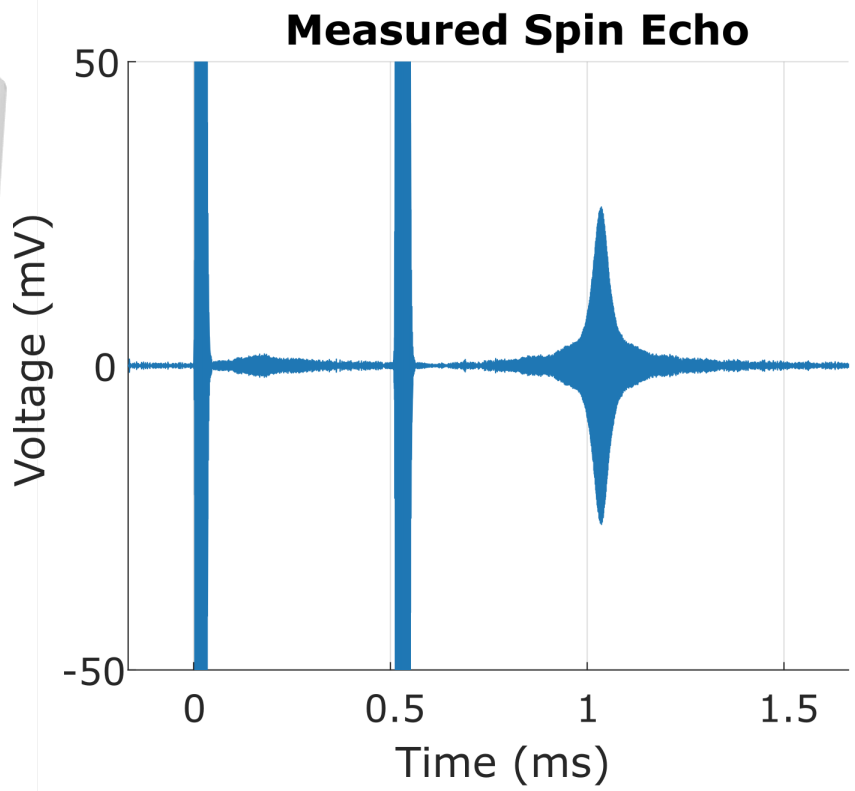


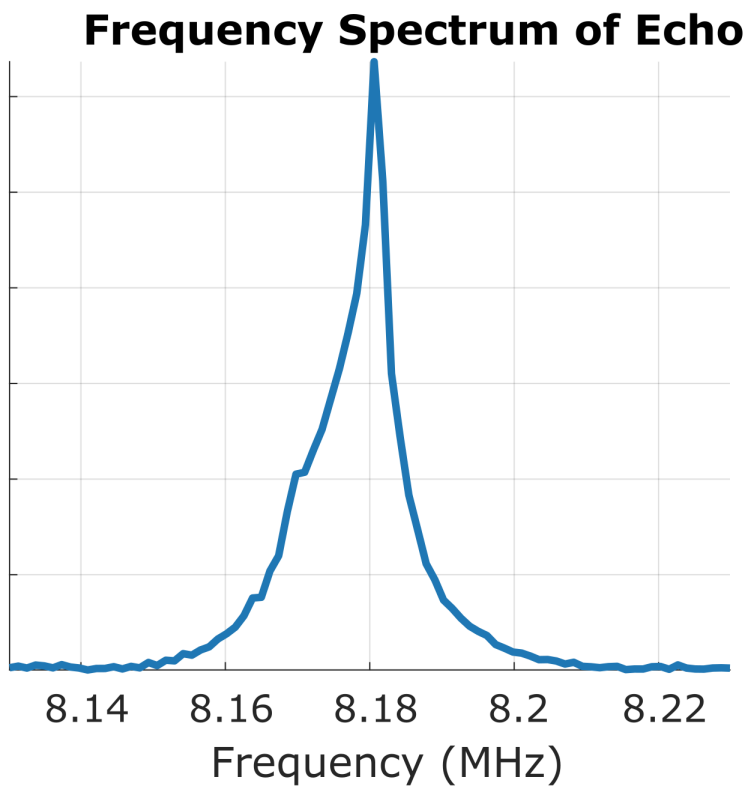
Spin echo experiment – water phantom







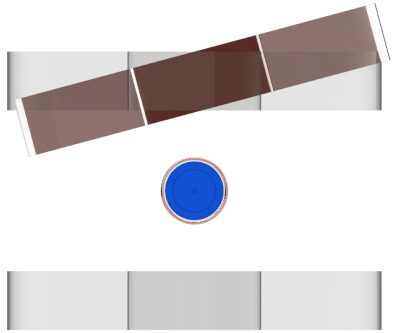


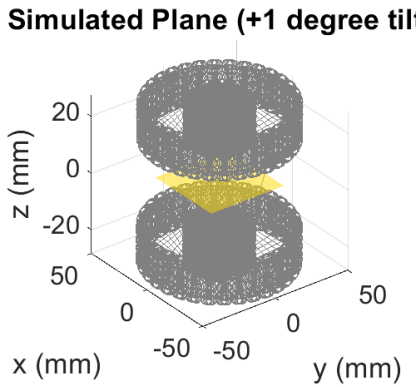


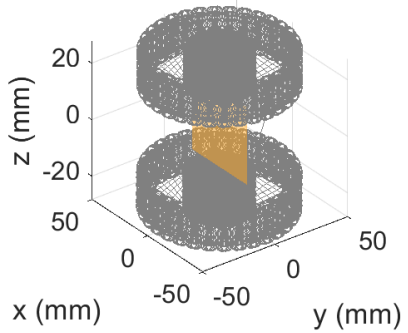
Sampling bandwidth, BW=125MHz; Readout points, n_s=12875; TE=1ms

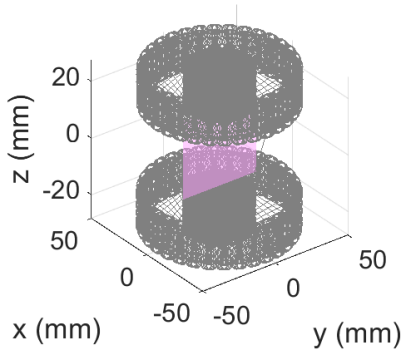
Simulated Field Maps

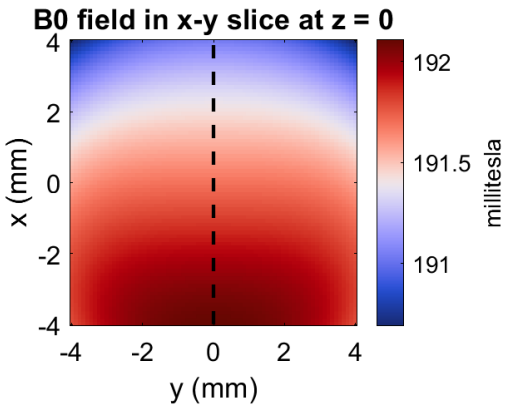
Mechanical Tilt Gradient

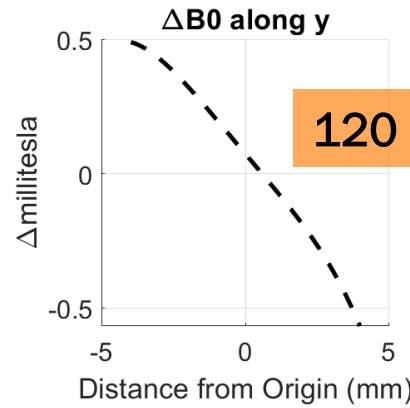




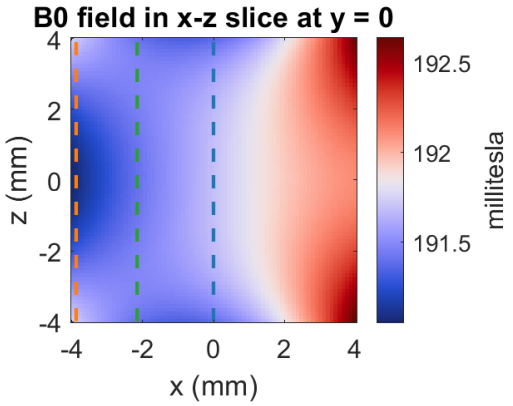


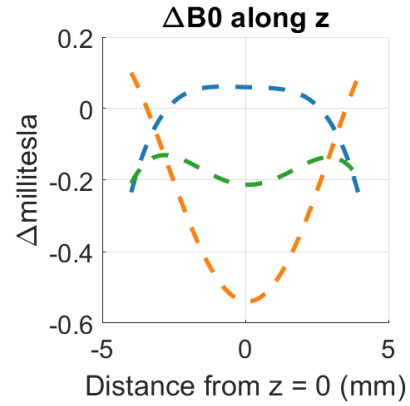


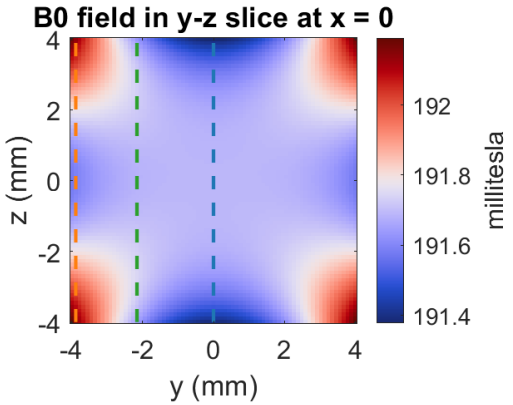


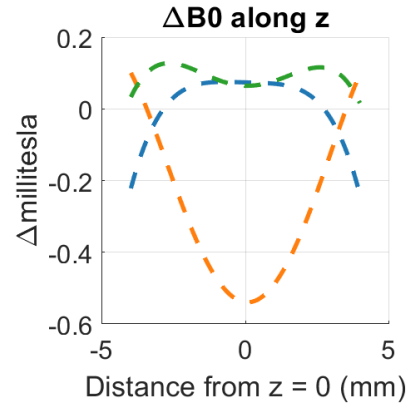


120 mT/m



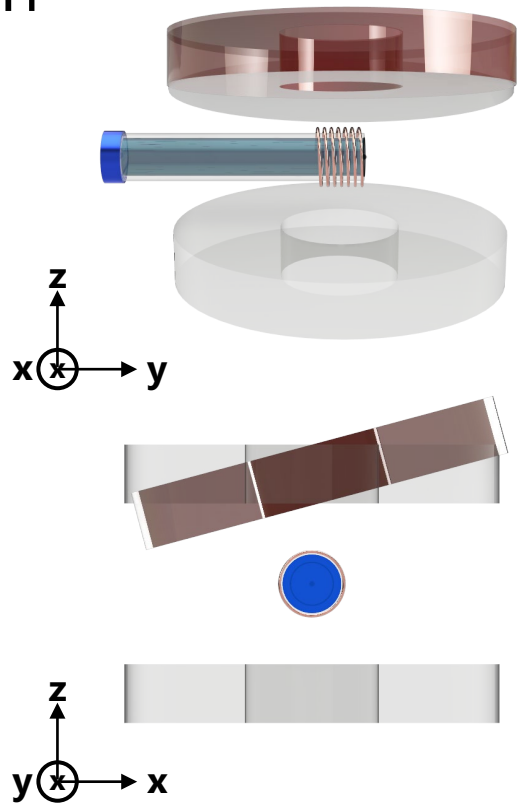


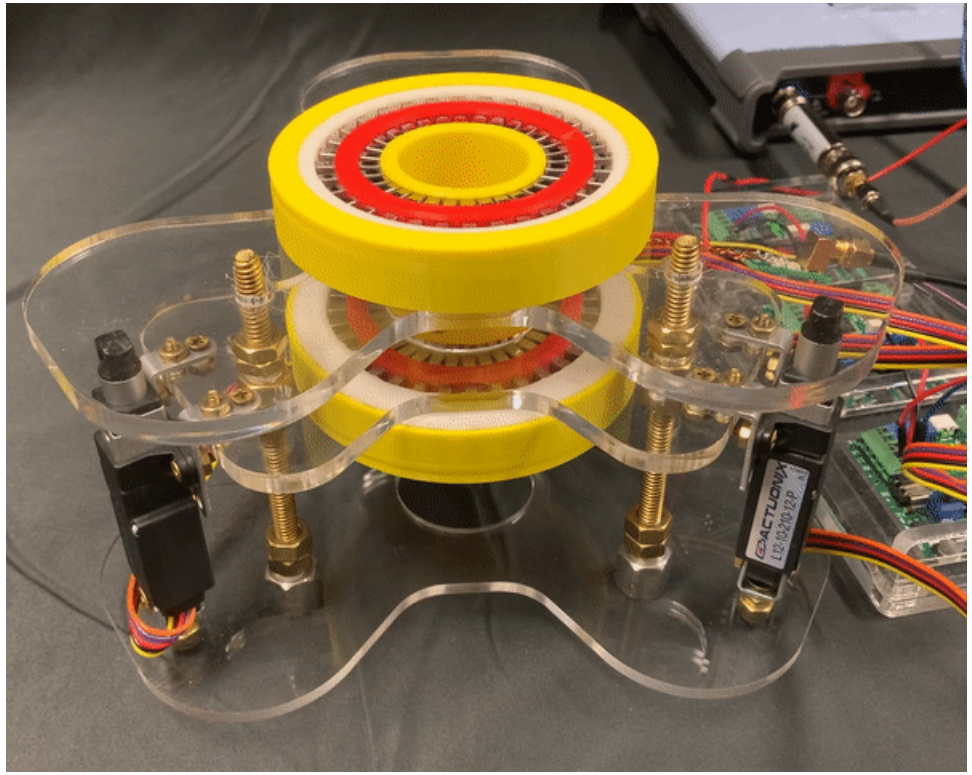




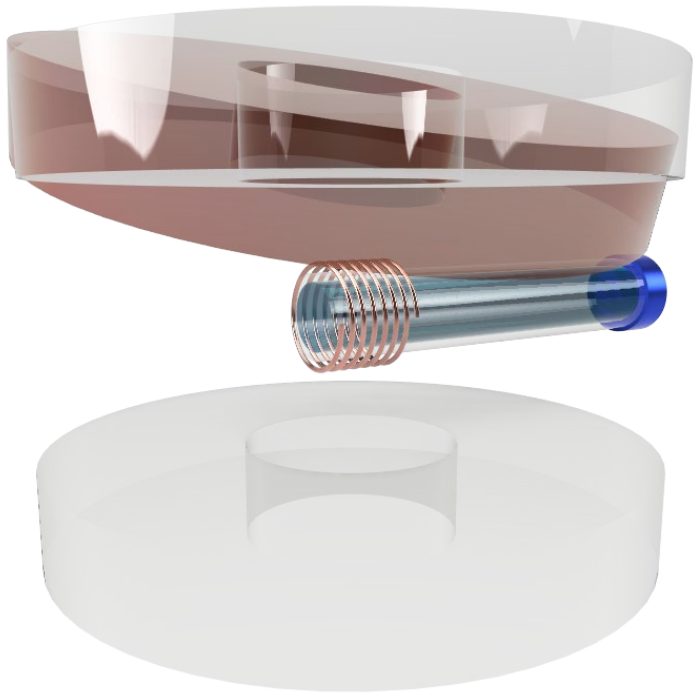
Mechanically-Generated Tilt Gradient

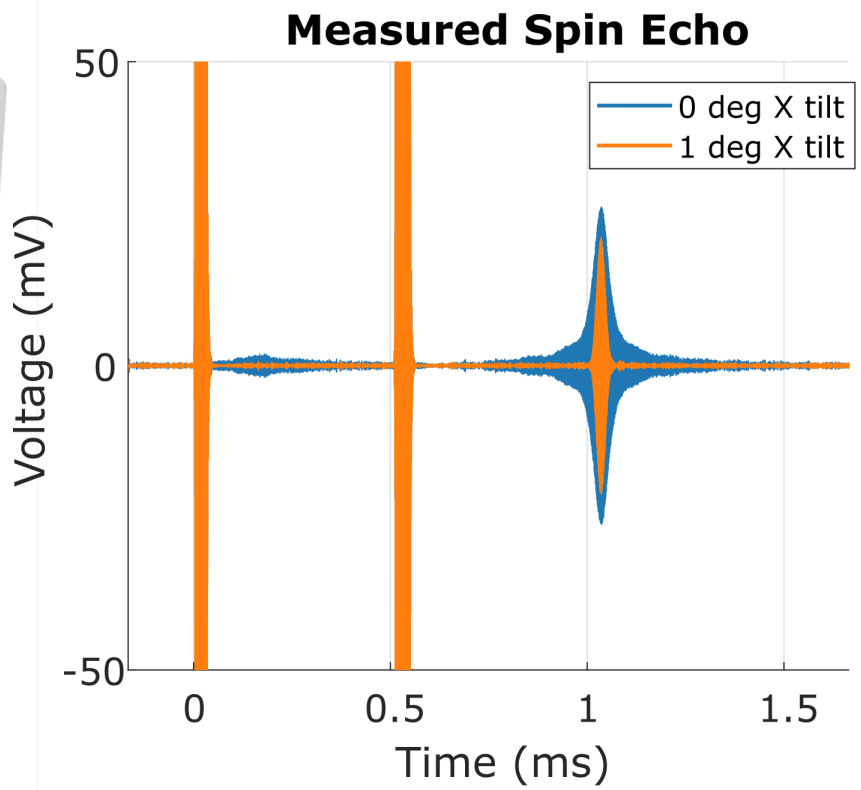
Linear actuators with position feedback (Actuonix L12-P)

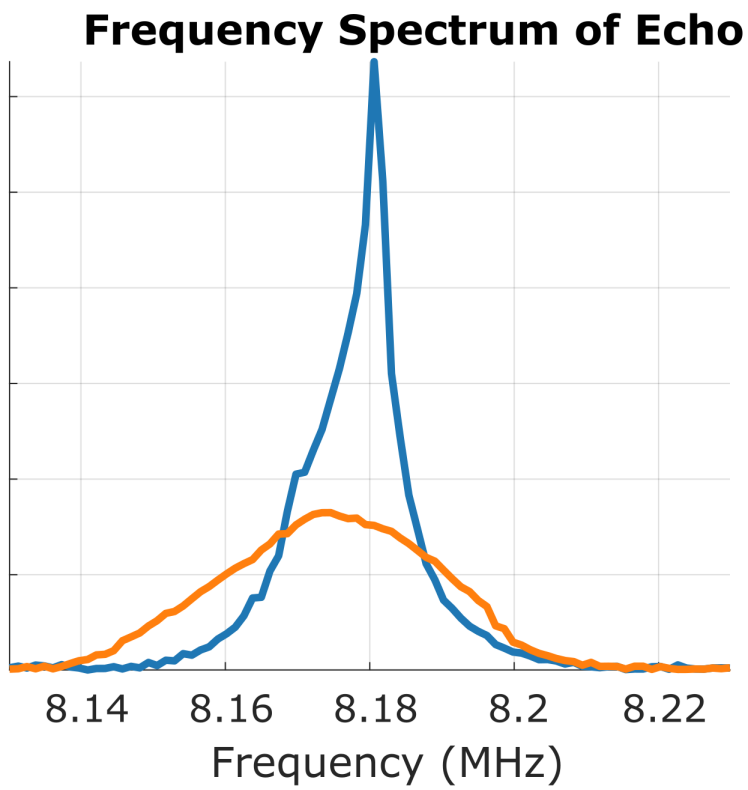




Spin echo experiment – water phantom with X gradient

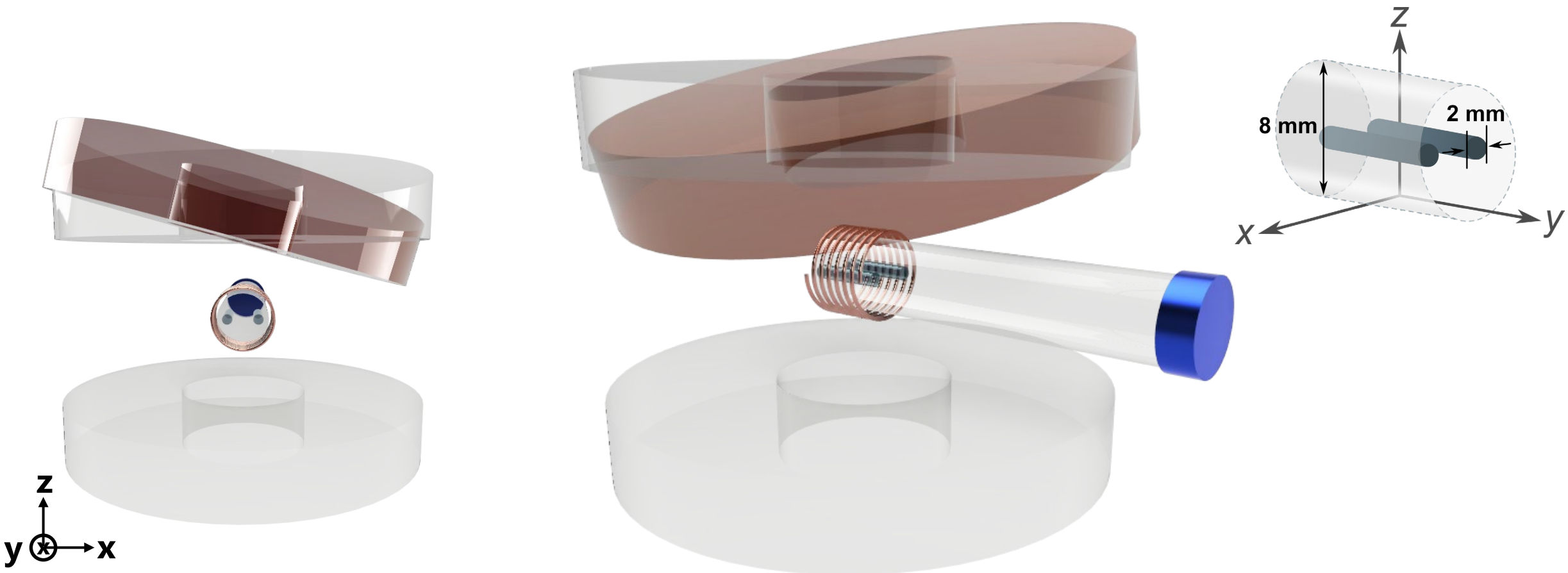




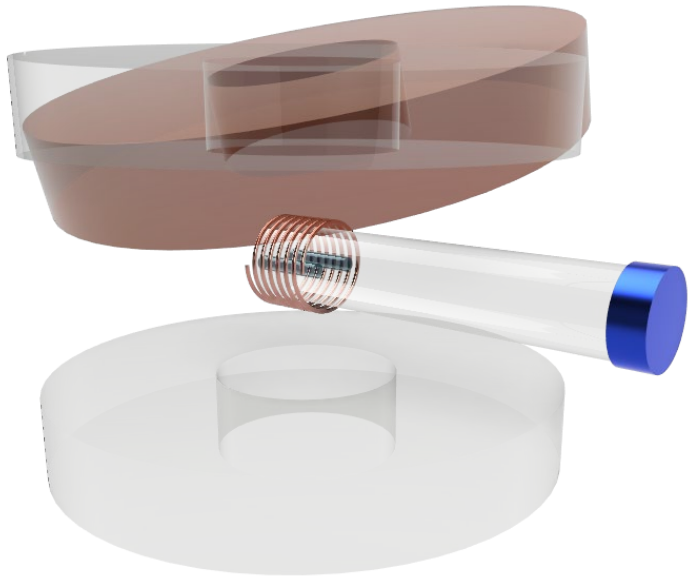


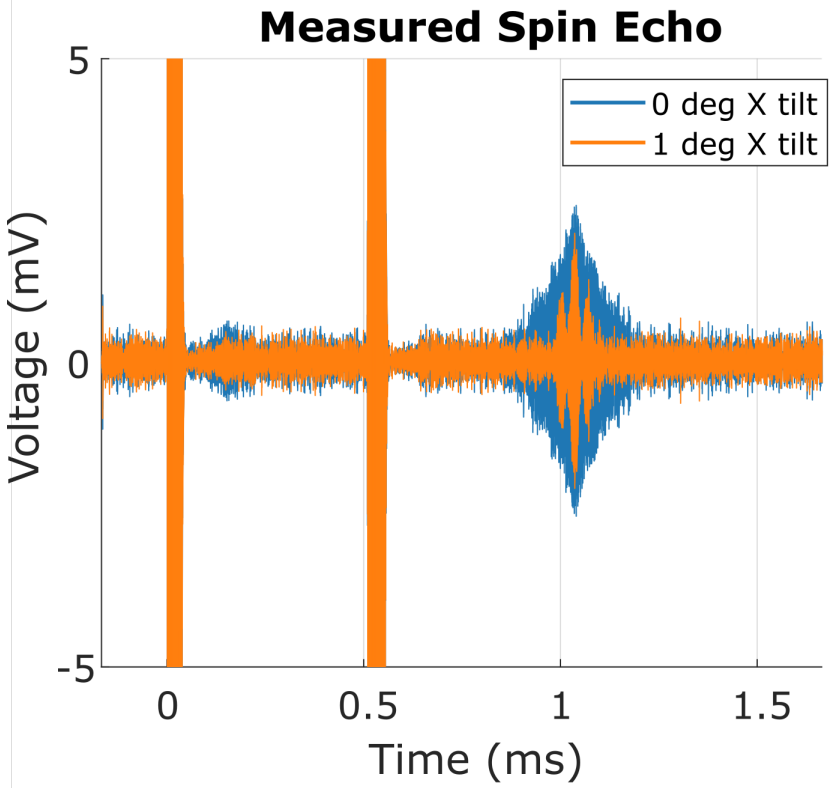
Sampling bandwidth, BW=125MHz; Readout points, n_s=12875; TE=1ms

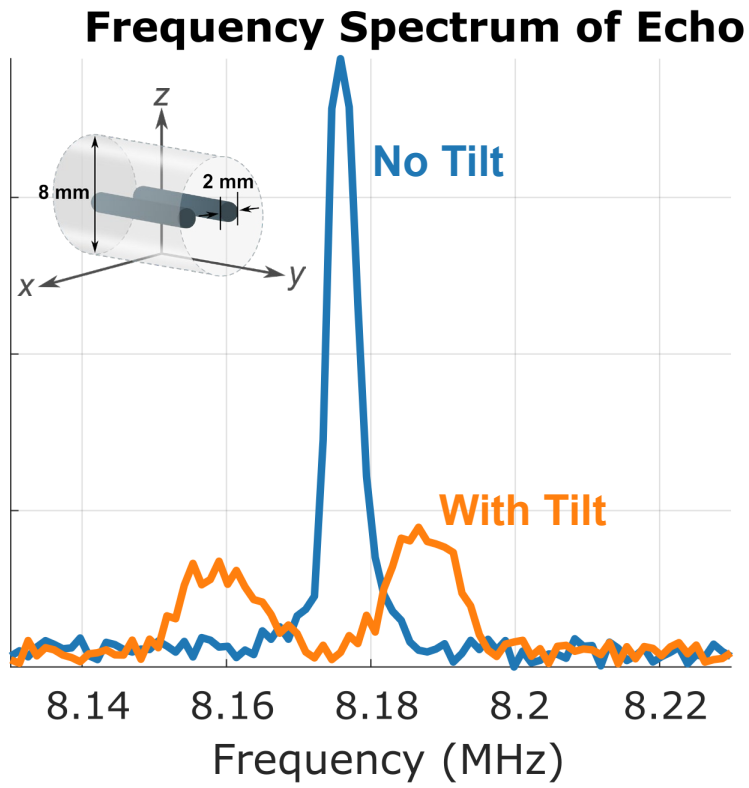
Spin echo experiment – 2 tube phantom with X gradient



Spin echo experiment – 2 tube phantom with X gradient

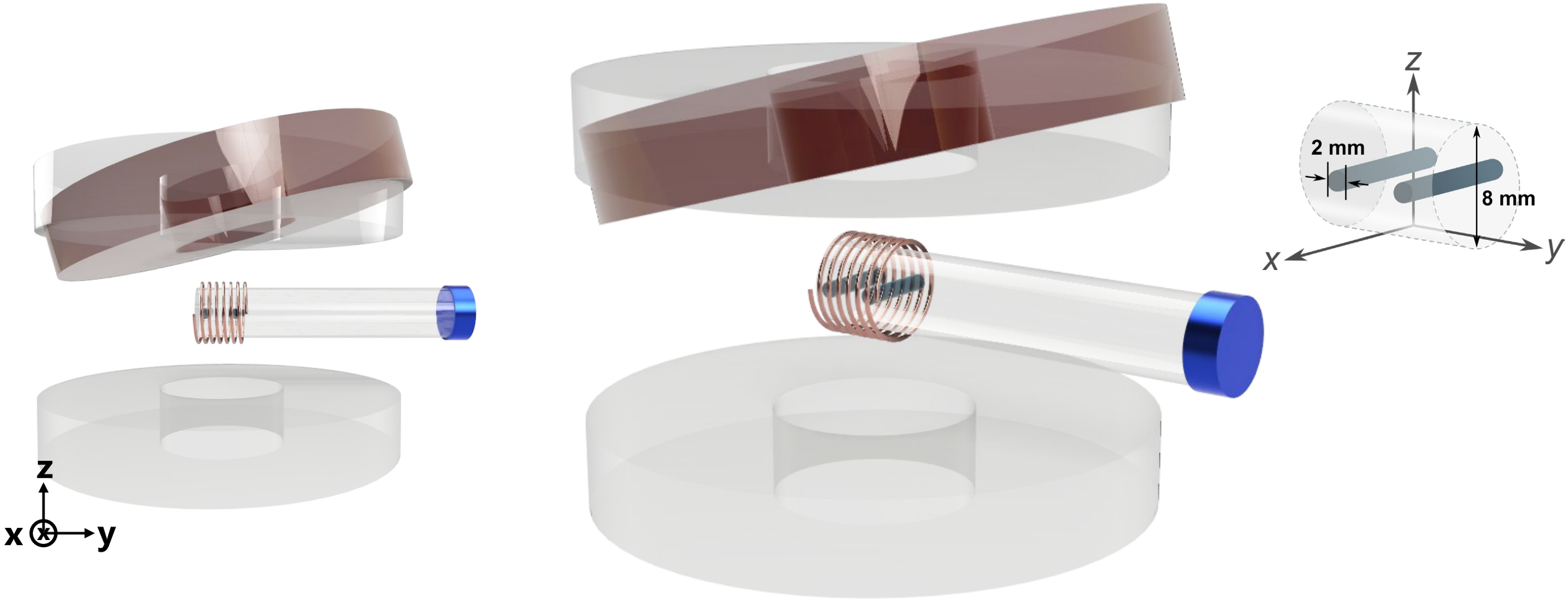




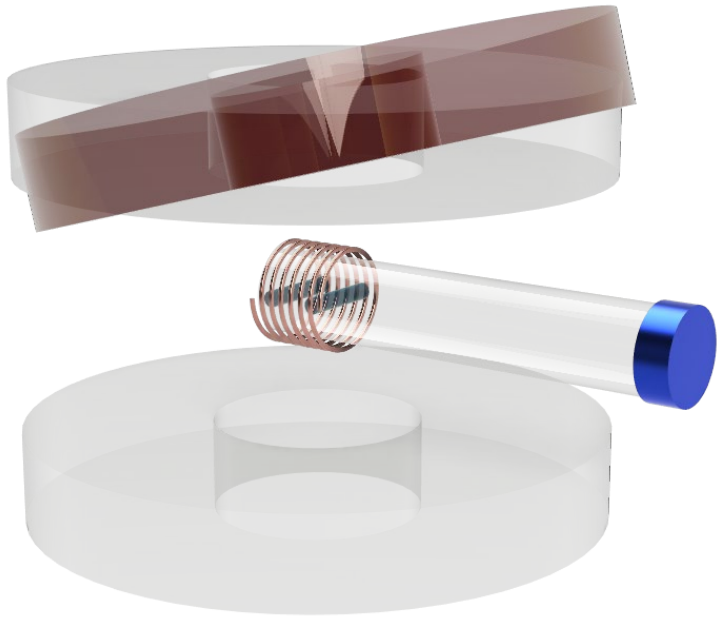


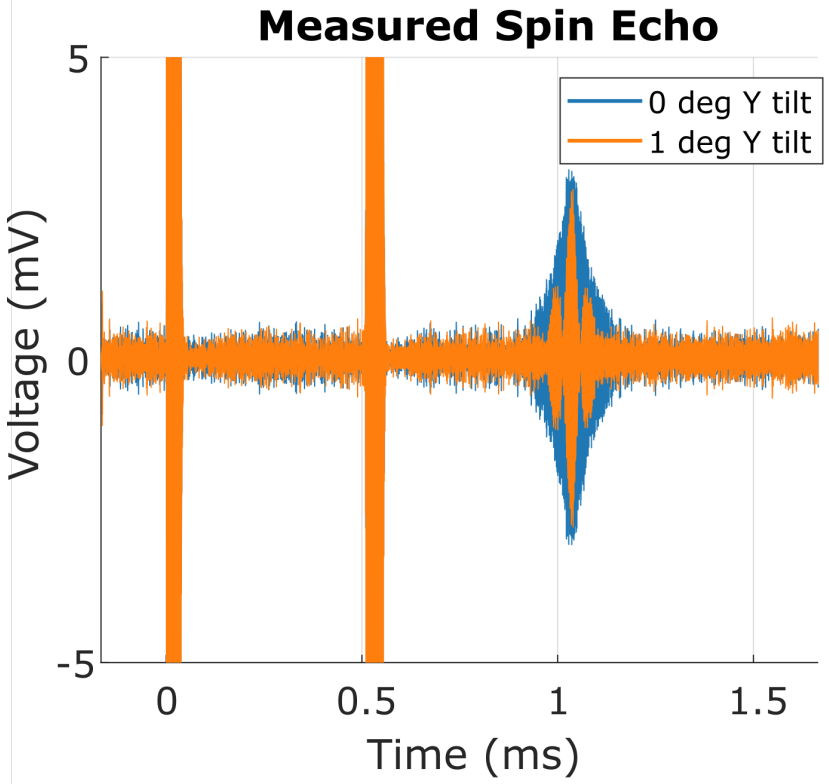
Sampling bandwidth, BW=125MHz; Readout points, n_s=12875; TE=1ms

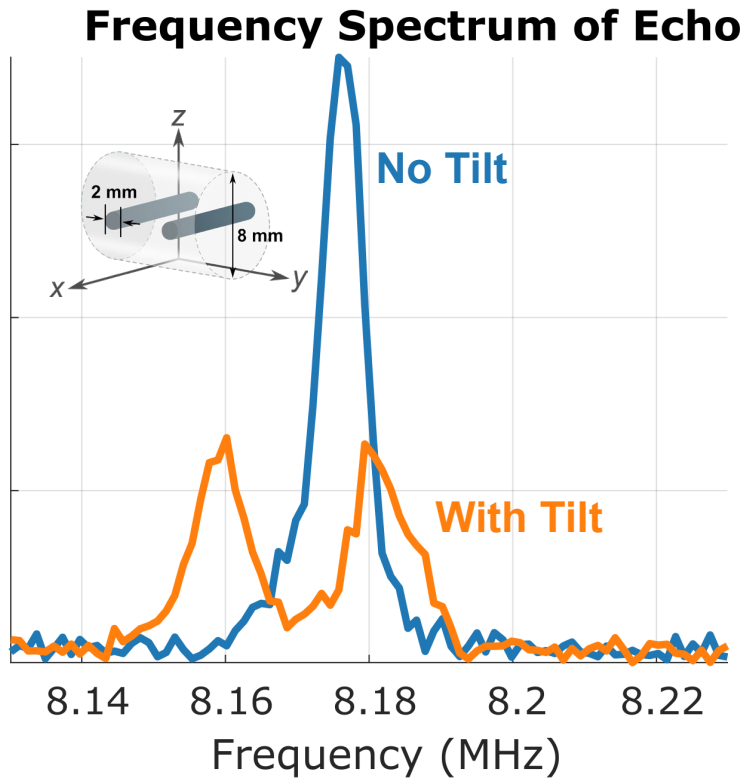
Spin echo experiment – 2 tube phantom with Y gradient



Spin echo experiment – 2 tube phantom with Y gradient



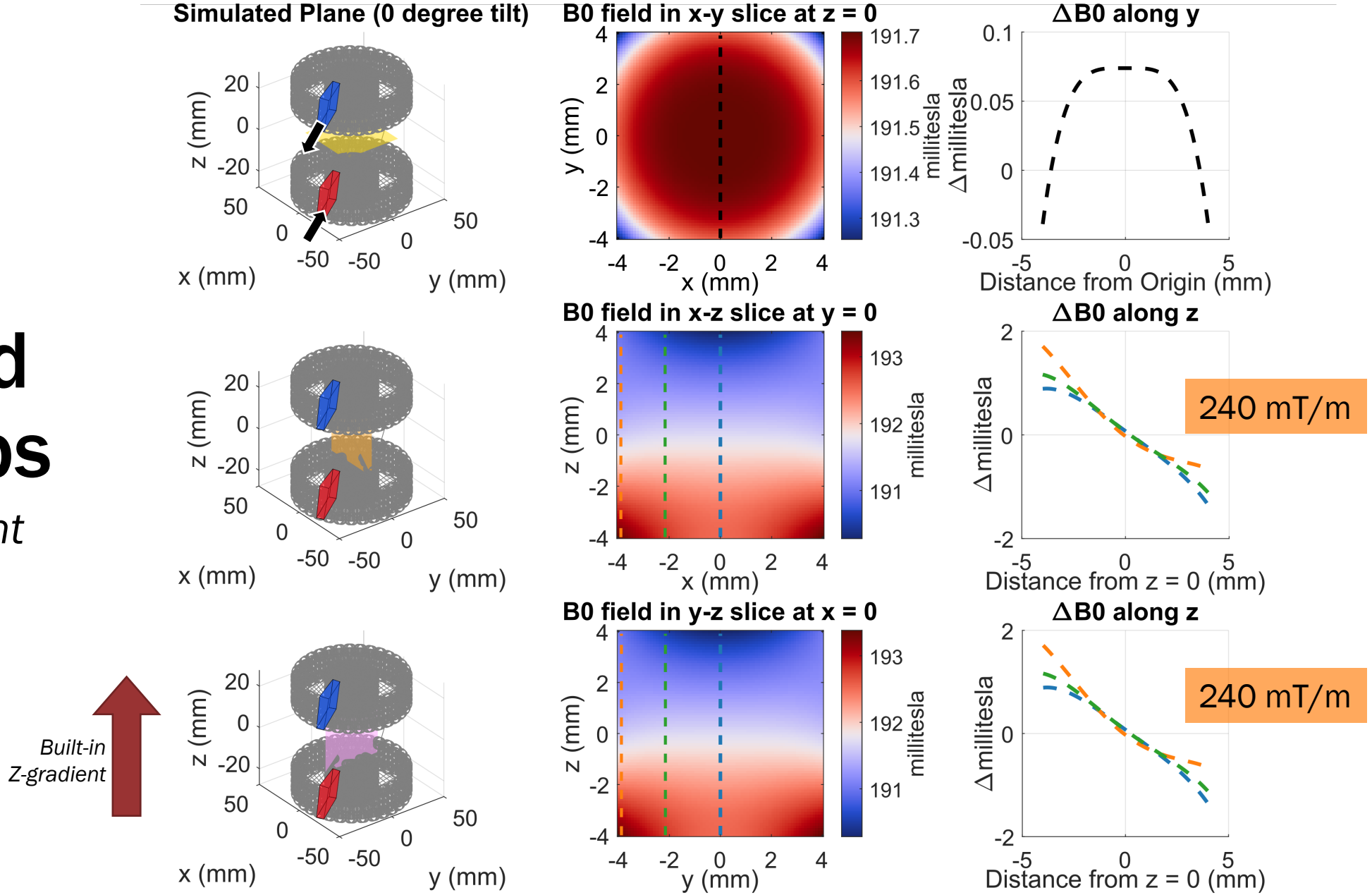




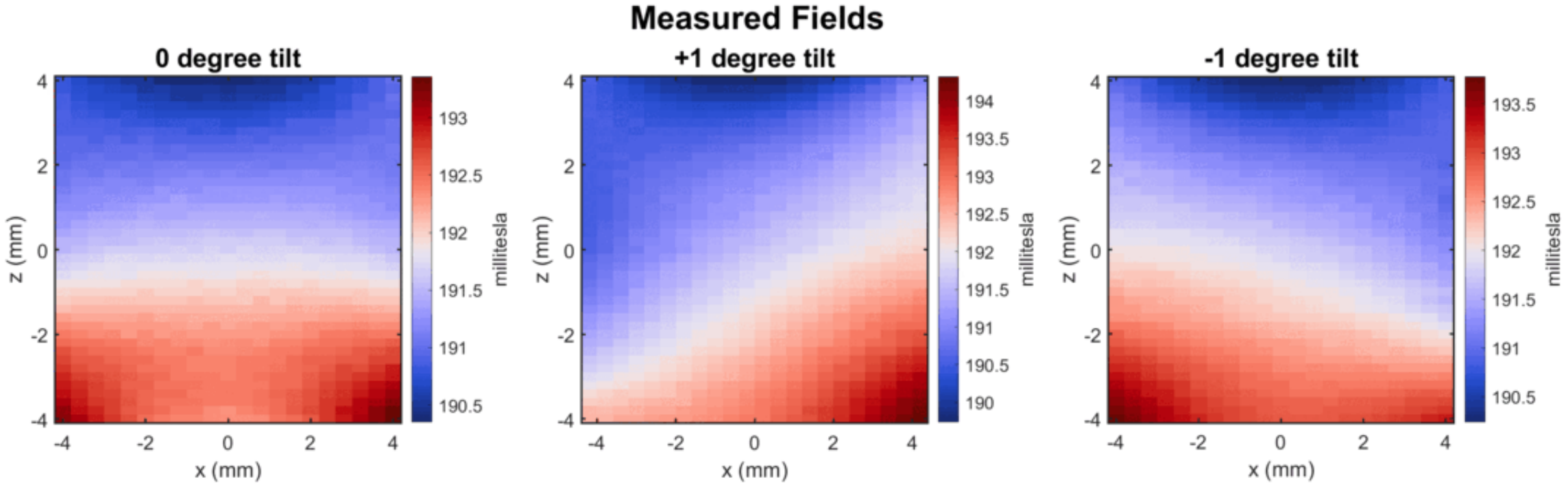
Sampling bandwidth, BW=125MHz; Readout points, n_s=12875; TE=1ms

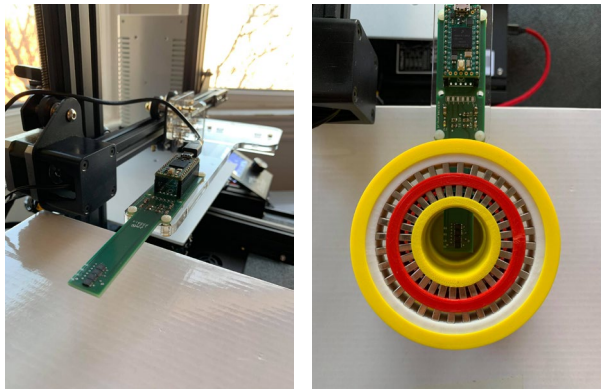
Simulated Field Maps

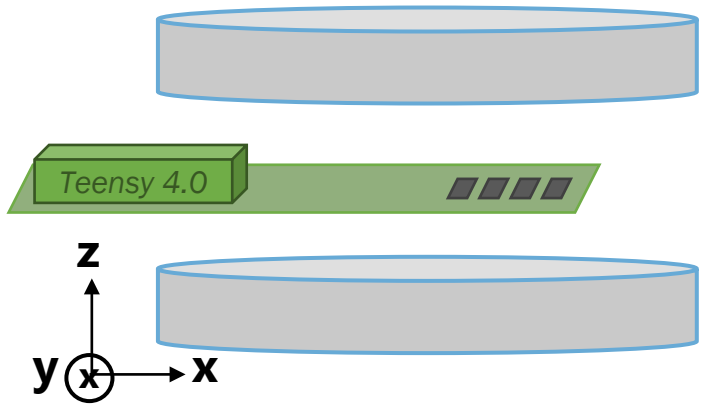
Built-in Z Gradient



Field map measurements – Z gradient + tilt

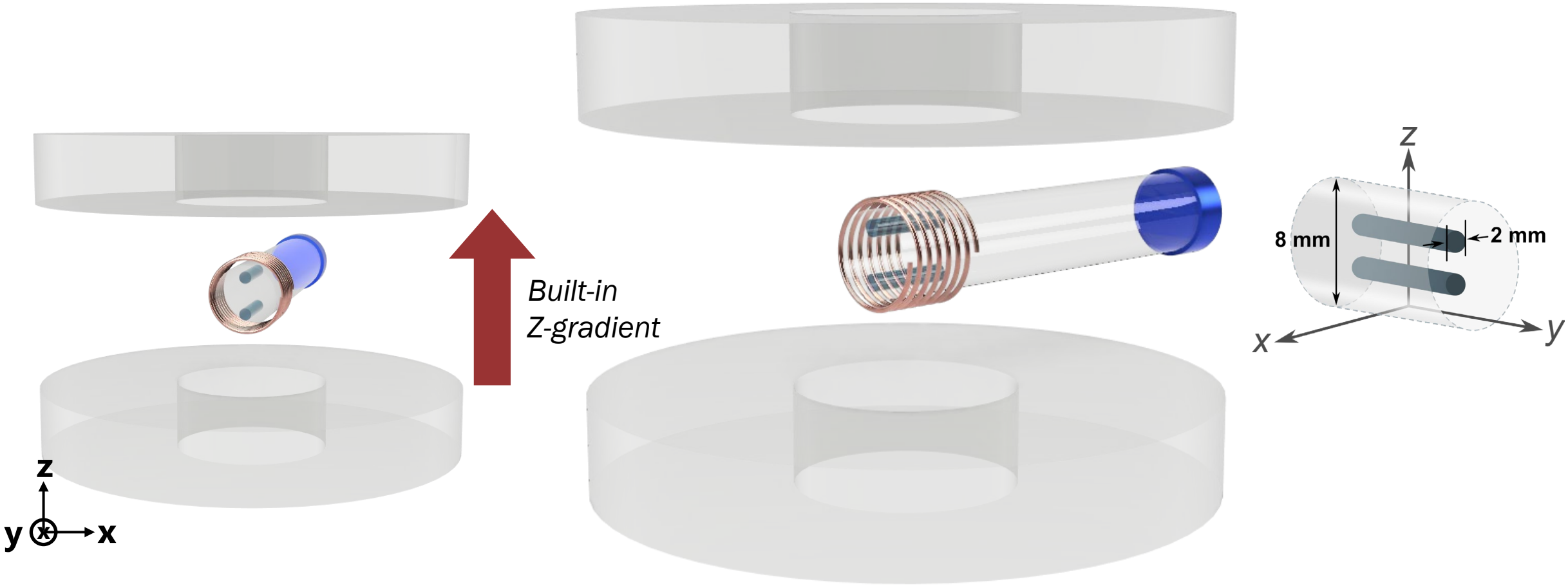




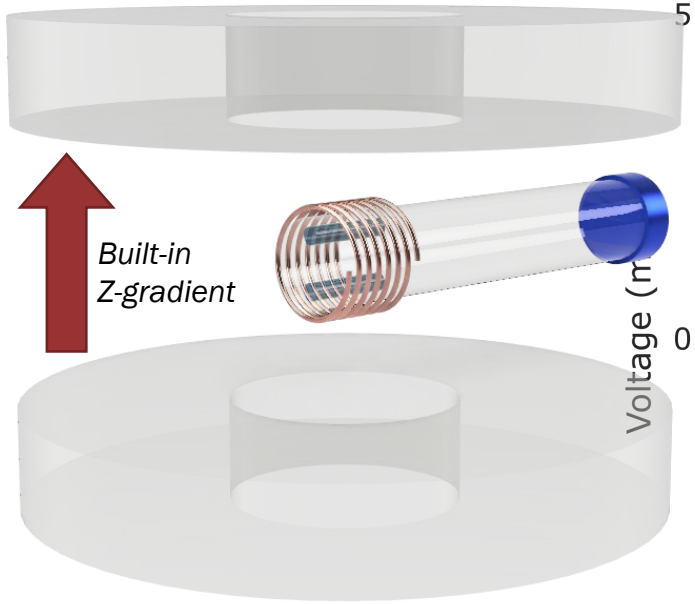


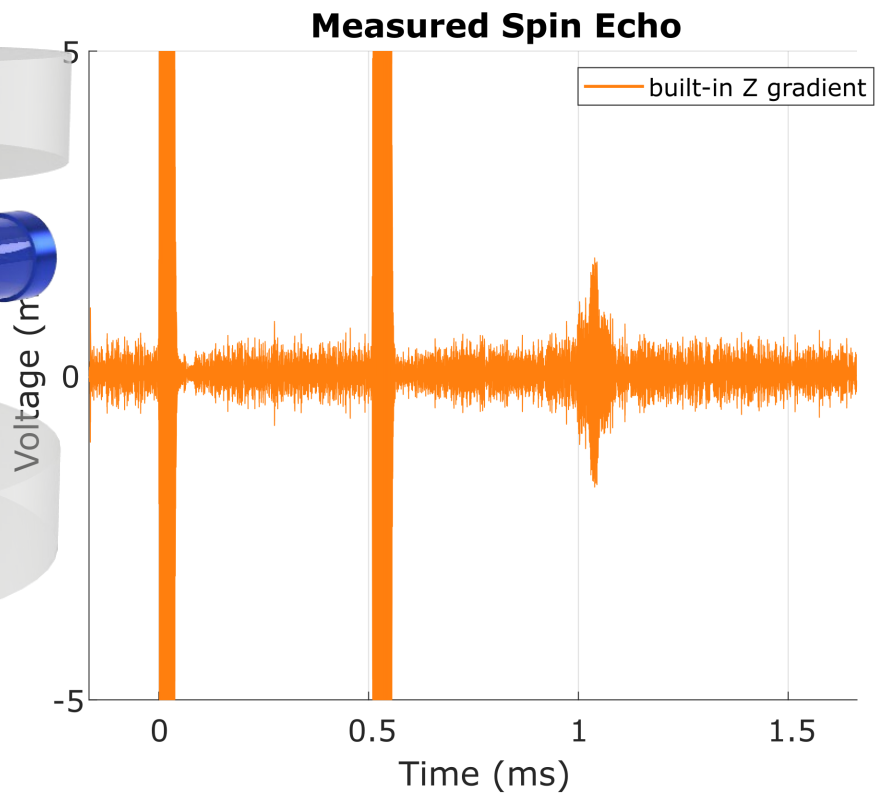
ALS31300 3D Linear Hall Effect Sensor (12-bit ADC)
Sensor range: ±2000 Gauss, Sensitivity: 1 LSB/Gauss
Sensitivity error: ±0.6%, Offset error: ±12 LSB
RMS noise: 1 LSB

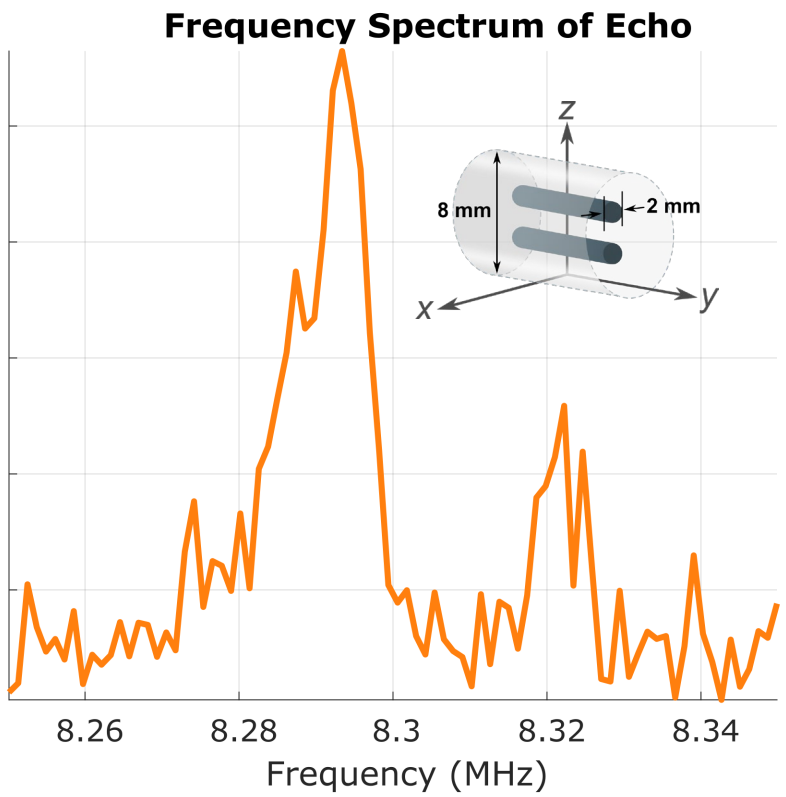
Spin echo experiment – 2 tube phantom with Z gradient



Spin echo experiment – 2 tube phantom with Z gradient

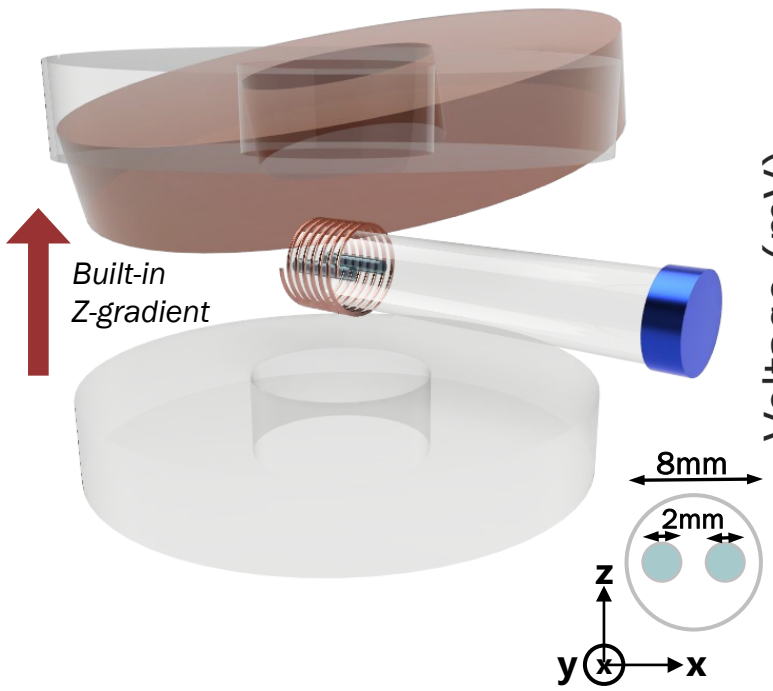


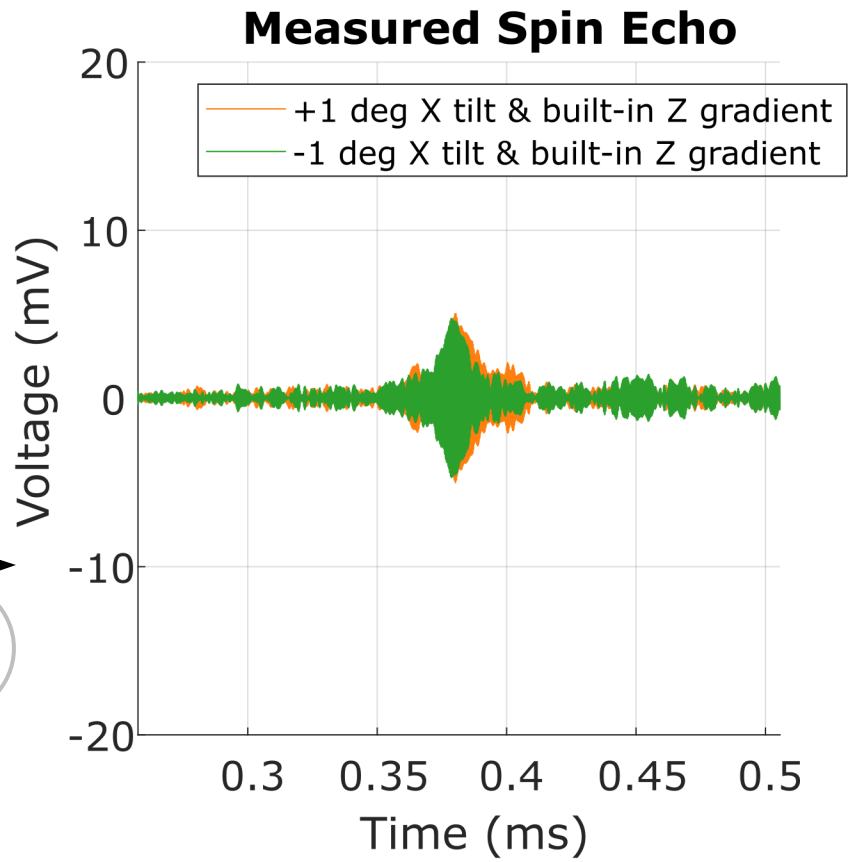


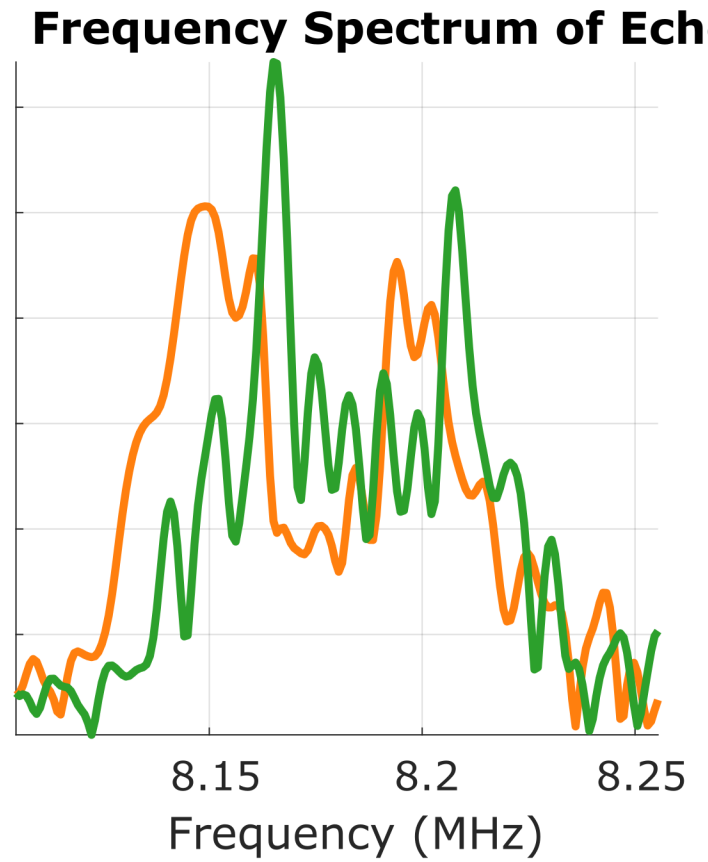


Sampling bandwidth, BW=125MHz; Readout points, n_s=12875; TE=0.38ms

Spin echo experiment – 2 tube phantom with X gradient and Z gradient







Sampling bandwidth, BW=125MHz; Readout points, n_s=12875; TE=0.38ms

Next Steps Towards Imaging

- We have demonstrated **X/Y/Z encoding** fields for hand-held MR

<u>Future work:</u>

- fast actuation (1 mm / 1 ms) for Turbo Spin Echo (TSE) imaging