Z2

Magnetoelectric Sensor Characterization

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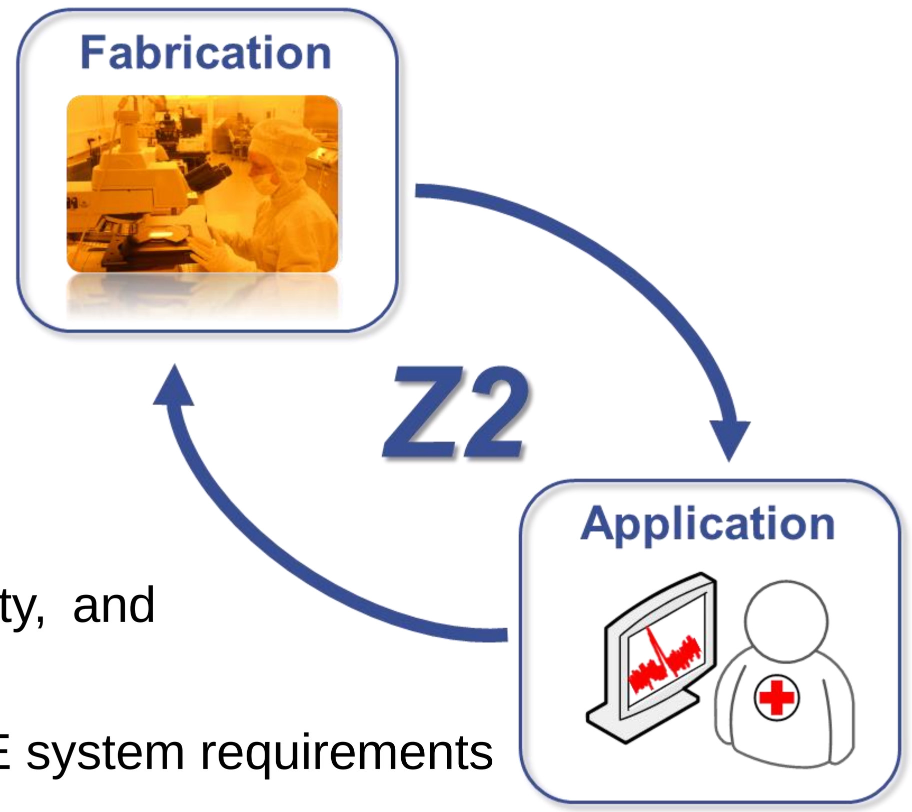
biomagnetic sensing SFB 1261

Motivation and Objectives



Motivation:

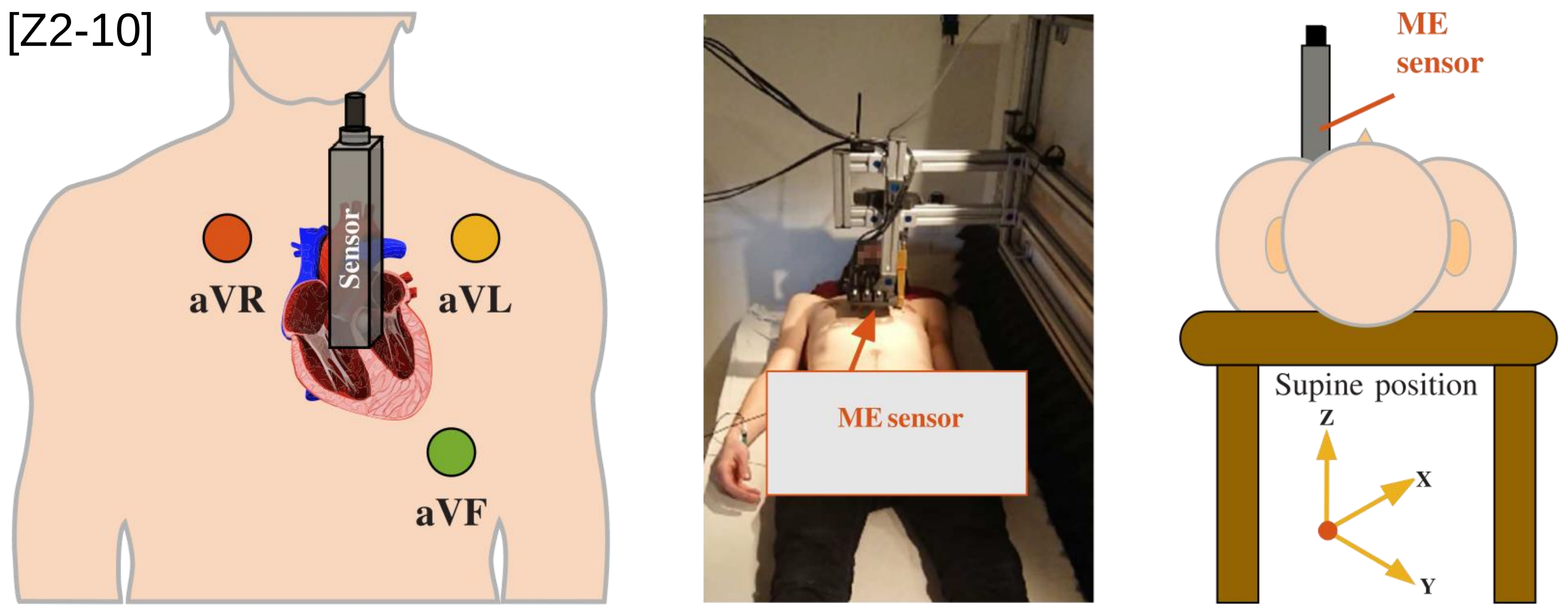
- Characterize ME sensors and resulting systems
- Standardize measurements and methods for all ME sensors
- Support optimum integration in biomedical applications

Main objectives:

- Quality assurance, reproducibility, and ME sensor system improvement
- Application support to ensure ME system requirements are satisfied in clinical settings
- Expert bodies collaboration to adapt existing evaluation concepts for high-performance magnetic field sensors
- Toolkit establishment for readout circuit selection and reuse

Results of the Second Funding Period

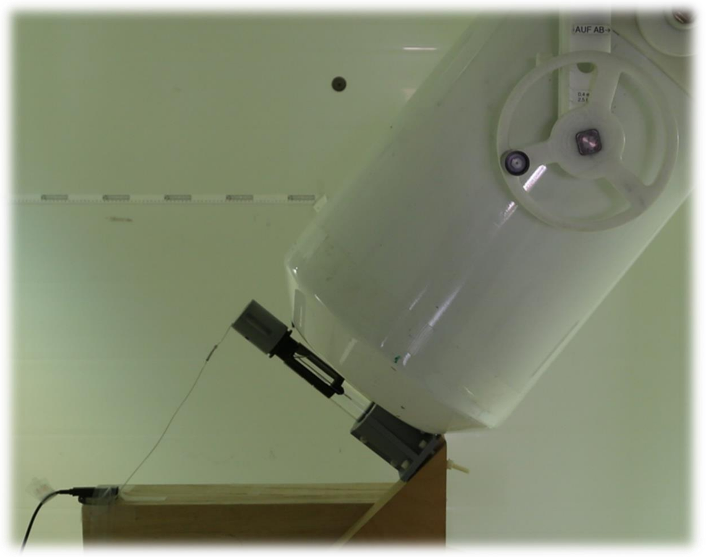
Shielded ME MCG feasibility study together with A1, A7, A10 and B10: [Z2-10]



Evaluation of new ME sensor concepts of projects A2 and A5 [Z2-P1]

Magnetic evaluation of DBS signal from a commercial stimulator with project T1:

- SQUID (VMS-304, PTB-Berlin)
- Optically Pumped Magnetometer (QZFM, Gen.2, QuSpin)
- xMR Sensor (TDK Corporation)



Defined quantitative ME evaluation in biomagnetic diagnostics [Z2-5]
➔ Editors choice article

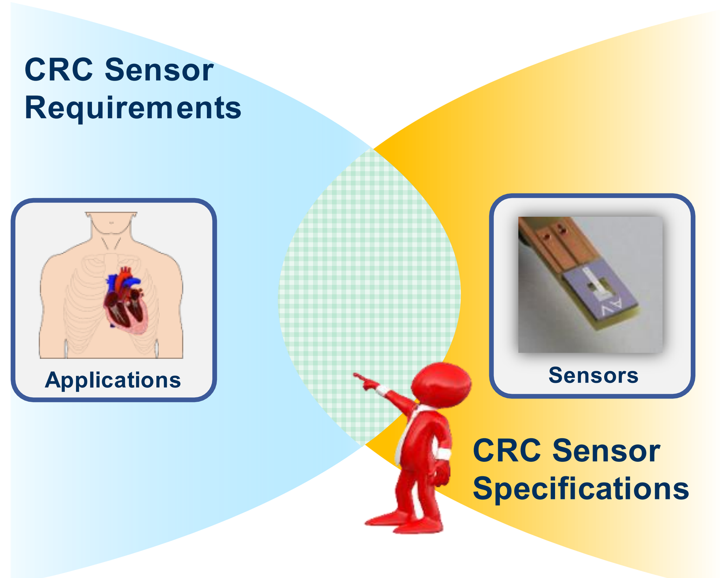
Quality classes established for MCG with project B10 [Z2-P2]

Development and evaluation together with B1 of different readout and circuit approaches [Z2-1, Z2-2, Z2-3, Z2-4, Z2-6, Z2-7, Z2-8]

Testing of proprietary camera-based (limited precision) localization for multichannel recording

In-depth ME sensor systems and application compatibility analysis within focus group F3

- Survey creation with Z1
  - Requirements **vs.** specification
- Identification of suitable candidates for a third funding period



Work Plan for Third Funding Period

Work plan

WP1: ME characterization / evaluation

a) Definition and extension of performance metrics, analysis methods, and measurement protocols incl. exchange with expert bodies (PTB, DGBMT)

b) Building a readout circuits toolkit for ME sensor systems

c) Characterization and evaluation of ME cantilever actuators

WP2: Technical application support

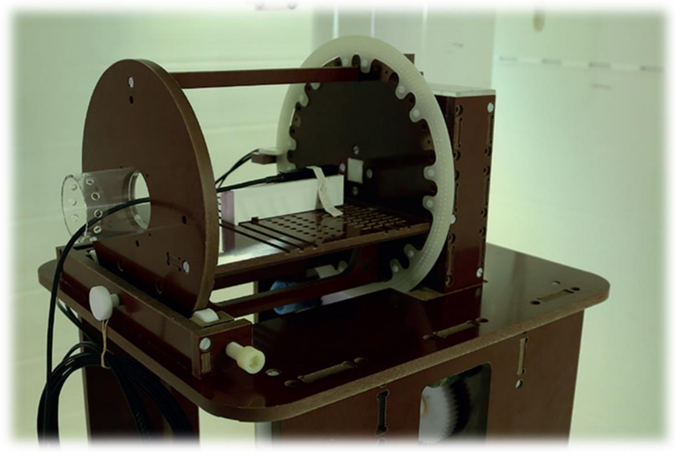
a) Investigate an application-oriented method for initializing ME sensor systems

b) Systematic ME conditioning protocol for clinical environments

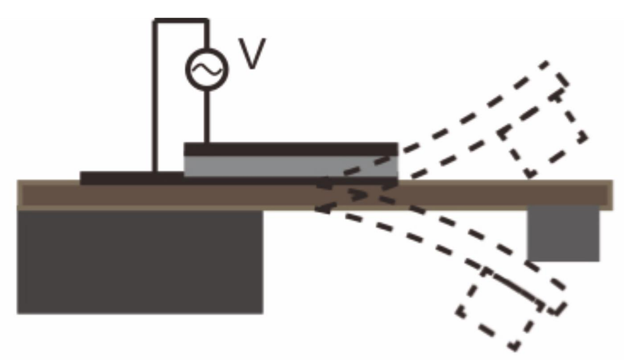
c) Support for integration of sensor systems, ensuring performance standards from WP1 a) are met

Prospect:

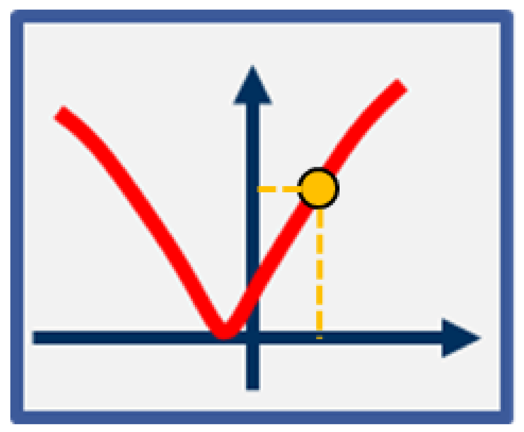
The methods and metrics developed are also helpful for assessing various high-performance magnetic field sensors



Sensor system test inside BMSR - 2.1 (PTB, Berlin)



Typical MEMS ME cantilever actuator [Z2-4]



Initializing/conditioning of ME sensor systems

Workplan		2024		2025				2026				2027				2028	
		3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
ME characterization / evaluation																	
WP1a	ME sensing elements and resulting ME sensor systems																
WP1b	Toolkit development for customized electronic readout circuits																
WP1c	ME cantilevers actuators																
Technical support of applications																	
WP2a	Systematic sensor initialization																
WP2b	Systematic sensor conditioning																
WP2c	Support for ME sensor system integration and validation																

Collaborations

A1: ME sensor characterization/evaluation
A2: Support with sensor characterization/evaluation
A4: Exploring new concepts and implementations to innovate and enhance the performance of electronics
A8: Support for SAW characterization/evaluation measurements
A7: ME sensor characterization
A9: SAW sensor characterization at carrier frequencies up to the GHz range
A10: Conduction of noise density measurement
B1: Takeover of analog hardware concepts of individual sensors for sensor characterization and related front ends for biomedical applications
B2: Takeover of digital signal processing routines for biomedical applications, assess online calibration during biomedical measurement and ME cantilever actuator characterization
B9: Hardware support
B10: Hardware support
B11: Hardware support
B12: Hardware support
B13: Hardware support and ME cantilever actuator characterization
Z1: ME sensor characterization/evaluation and ME cantilever actuator characterization

Participation in focus groups

F3: Comparison of sensor concepts
F6: Biomedical applications

Funds Requested

1 Postdoctoral researcher, consumables: 45 k€

[Z2-1] Wang, H.; Arbustini, J.; Elzenheimer, E.; Schell, V.; **Höft, M.;** Quandt, E.; Schmidt, G.; Heidari, H.; Bahr, A.: 29th IEEE International Conference on Electronics, Circuits and Systems (2022).

[Z2-2] Wolframm, H.; Schell, V.; Quandt, E.; **Höft, M.**; Bahr, A.: Spintronics XV, SPIE, (2022), Vol. 12205, pp. 25-31.

[Z2-3] Muñoz, J.; Arbustini, J.; Elzenheimer, E.; Hoffmann, J.; Thormählen, L.; Hayes, P.; Niekiel, F.; Heidari, H.; **Höft, M.**; Quandt, E.; Schmidt, G.; Bahr, A: 29th IEEE International Conference on Electronics, Circuits and Systems (2022).

[Z2-4] Arbustini, J.; Muñoz, J.; Wang, H.; Elzenheimer, E.; Hoffmann, J.; Thormählen, L.; Hayes, P.; Niekiel, F.; Heidari, H.; **Höft, M.;** Quandt, E.; Schmidt, G.; Bahr, A.: Current Directions in Biomedical Engineering, (2022), Vol. 8, No. 2, pp. 309-312.

[Z2-5] Elzenheimer, E.; Bald, C.; Engelhardt, E.; Hoffmann, J.; Hayes, P.; Arbustini, J.; Bahr, A.; Quandt, E.; **Höft, M.**; Schmidt, G: Quantitative Evaluation for Magnetoelectric Sensor Systems in Biomagnetic Diagnostics. Sensors, (2022), 22(3), 1018.

[Z2-6] Simmich, S.; **Rieger, R.**: 17th Conference on Ph. D. Research in Microelectronics and Electronics, (2022), pp. 337-340.

[Z2-7] Spetzler, B.; Wiegand, P.; Durdaut, P.; **Höft, M.;** Bahr, A.; **Rieger, R.;** Faupel, F.: Sensors, (2022), 21(22), 7594.

[Z2-8] Simmich, S.; Bahr, A.; **Rieger, R.:** Electronics, (2021), 10(13), 1522.

[Z2-9] **Rieger, R.;** Rif'an, M.: IEEE Transactions on Circuits and Systems I: Regular Papers, (2018), 65(8), 2422-2430.

[Z2-10] Elzenheimer, E.; Hayes, P.; Thormählen, L.; Engelhardt, E.; Zaman, A.; Quandt, E.; Frey, N.; Höft, M.; Schmidt, G.: IEEE Sensors Journal, (2023), 23 (6), 5660-5669.

[Z2-P1] Gerhardt, M.; Zimoch, L.; Dorn, C.; Elzenheimer, E.; Bald, C.; Lerg, T.; R. Hoffmann, J.; Kaps, S.; Höft, M.; Schmidt, G.; Wulfinghoff, S.; Adelung, R.: Nano Energy, (2023), 115, 108720.

[Z2-P2] Engelhardt, E.; Zaman, A.; Elzenheimer, E.; Frey, N.; Schmidt, G.: Current Directions in Biomedical Engineering, (2022), 8(2), 691–694.