A4

ΔE-Effect Sensors

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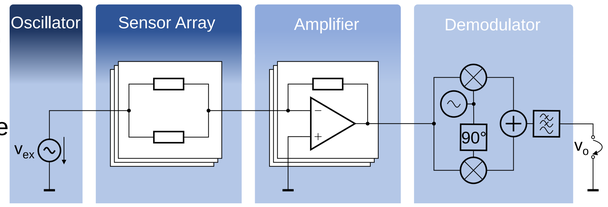
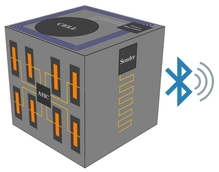
biomagnetic sensing SFB 1261

Motivation and Objectives

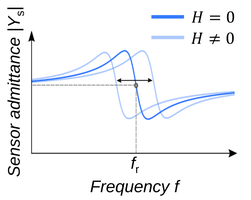
Main Objective
Miniaturized and *wireless* 3D sensor system with integrated ASIC electronics that is *highly adaptable* to the use case and provides easily accessible real time measurements for the application projects

System features
- Low power consumption
- High spatial resolution
- Large bandwidth
- High dynamic range
- Multi-directional detection
- Wireless communication

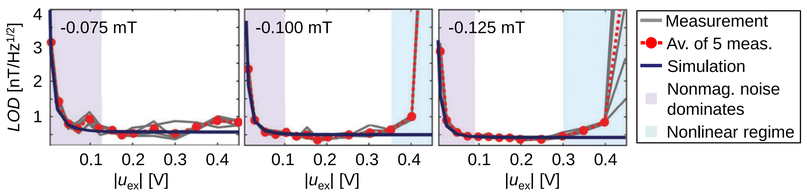




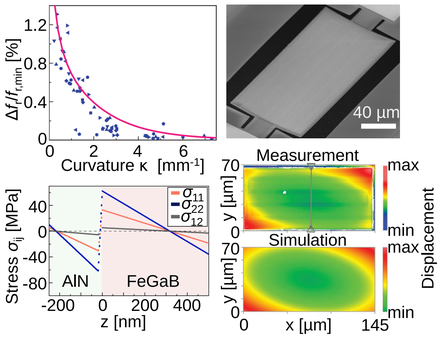
Sensor concept
A magnetic field H changes the resonator's stiffness, and thus, its resonance frequency f_r, which modulates the sensor current induced by an excitation voltage



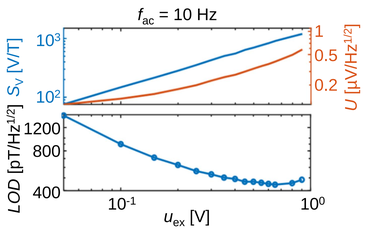
Results of the Second Funding Period



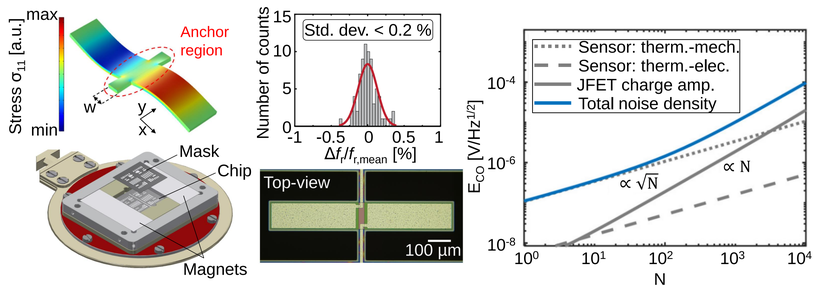
Understanding the origin of the magnetic noise with combined system model [A4-3]



Contour-mode micro resonators [A4-5]

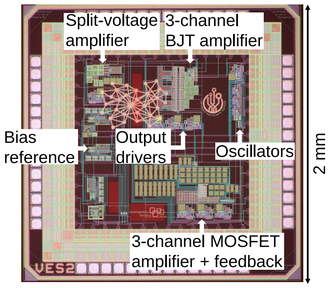


LOD < 450 $\mathrm{pT}/\sqrt{\mathrm{Hz}}$ (10-50 Hz) with exchange-biased multilayers at zero bias [A4-8]

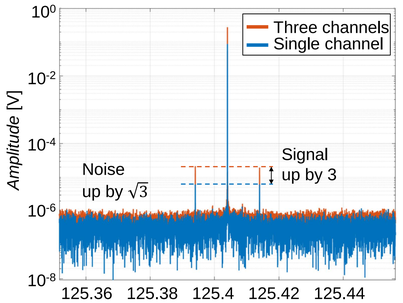


Miniaturized ΔE-effect sensors with a standard deviation of f_r < 0.2 % [A4-6]

Signal-noise model for sensor arrays [A4-4]



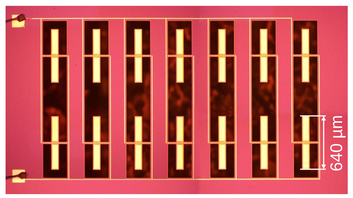
ASIC for excitation and signal amplification [A4-10]

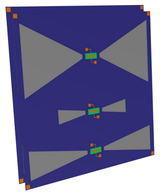


SNR improvement by $\sqrt{n}$ when using n sensors

Work Plan for Third Funding Period

WP1: Multiscale sensor and matrix modeling
- Expand existing single sensor models to sensor matrices
- Statistical analysis
- Data-driven modeling





WP2: Vector-enabled sensor arrays and characterization
- Explore use of different array configurations
- Introduce flux guides/concentrators
- Improve LOD, optimize spatial and angular resolution

WP3: Sensor interface electronics
- Low-power integrated system matched to the sensor arrays
- Crystal-referenced frequency-tunable on-chip oscillators
- Multi-channel low-noise amplification, demodulation, filtering, analog-to-digital conversion

WP4: Electronic system for wireless sensing
- Wireless data transmission
- Power supply with batteries or RF-harvested power

WP5: Realization of 2D matrices and 3D sensing cubes
- Fully self-contained sensing units
- Wireless detection of magnetic fields in 3D
- Untethered sensing towards application in medical projects

Prospect:
We will show a structured path for tailoring sensors to specific application scenarios for individual sensors as well as multi-sensor arrangements. The sensor concepts with integrated electronics will enable the ubiquitous and simple deployment of magnetic sensors applicable to a diverse set of measurement problems.

	AG Rieger	2024		2025				2026				2027				2028	
	AG Spetzler	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
WP 1	Multiscale modeling																
WP 2	Vector enabled arrays																
WP 3	Interface electronics																
WP 4	Wireless sensing																
WP 5	Sensing cubes																

Collaborations

A1: Provides expertise on advanced magnetic multilayers and fluxgates
A6: Improvement of process parameters in FeCoSiB deposition
A8: Joint analysis of time-dependent behavior of ΔE-effect sensors
A10: Magnetic characterization and modeling support of magnetic noise
B1: Exchange on electronic circuit concepts for sensor readout
B2, B9, B10, B11 (N): Provision of sensor samples for research in biomedical measurement and signal processing applications
Z1: Support with MEMS post-processing
Z2: Exchange of information and samples for improvement in sensor electronics

Participation in focus groups
F1: Magnetic Layers
F2: Modelling
F3: Comparison of Sensor Concepts
F5: Concepts based on ΔE-effect

Funds Requested

2 Doctoral researchers, consumables: 68.5 k€

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[A4-10] Simmich, S., Wiegand, P. & **Rieger, R.**: IEEE Asia Pacific Conference on Circuits and Systems (2023). - **A4**

INNOMAG **Dissertation prize** of the Division of Magnetism of the DPG, 2021 DPG