Microscale sensor systems based on AMR sensors

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Introduction

Magnetic field sensors are essential components of several industrial, biomedical and consumer electronics applications. Sensors based on the anisotropic magnetoresistance (AMR) are particularly attractive owing to their relatively simple fabrication process (which makes their downscaling straightforward) and to their robust structure (which allows them to be fabricated on a wide variety of substrates).

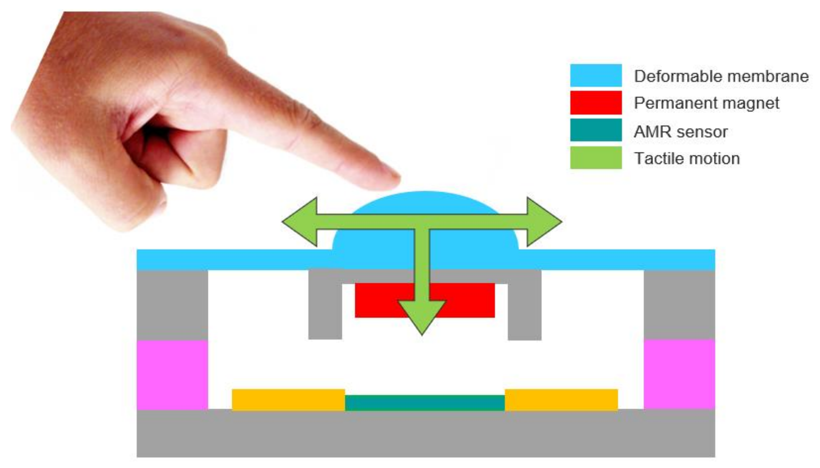
Here, we discuss the development of magnetic microsystems based on the detection and reconstruction of the motion of permanent magnets via properly designed arrays of AMR sensors.

Integration of magnets and magnetic sensors into microsystems

The basic general structure of this class of microsystems consists of two main parts: (i) a set of AMR sensors (located at the bottom) and (ii) a small permanent magnet (on top), embedded within a deformable membrane and therefore capable of moving relative to the magnetic sensors as a result of the external solicitation generated by the physical observable of interest.

The concept can be applied for a wide spectrum of sensing solutions:

- tactile sensors
- pressure sensors
- accelerometers
- (micro-)flow sensors

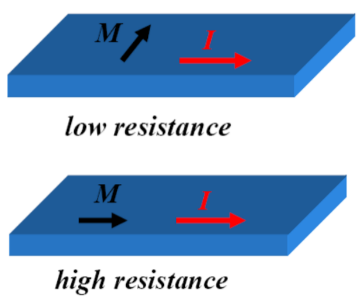


Magnetic microsystem family

- Coupling to external world
- Flexible frame
- Magnetic sensor
- Magnetic map

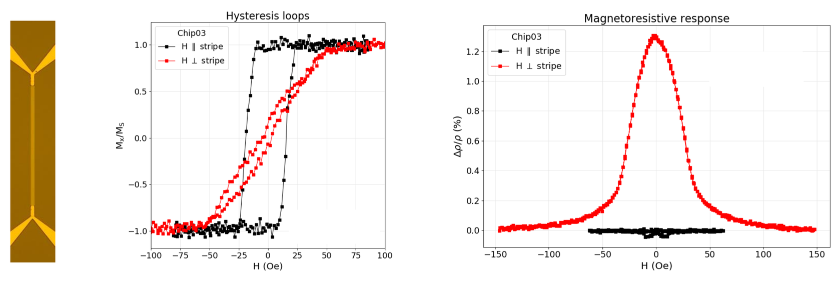
AMR sensors

Resistance change in a ferromagnetic material according to the relative orientation of current and magnetization.

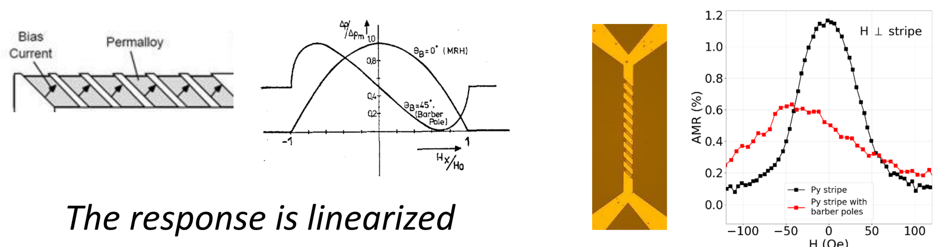


Sensor response:

- ferromagnetic (i.e., Permalloy) stripe

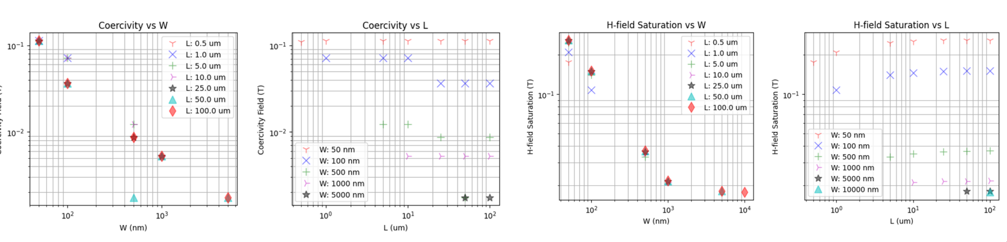


- stripe with barber poles



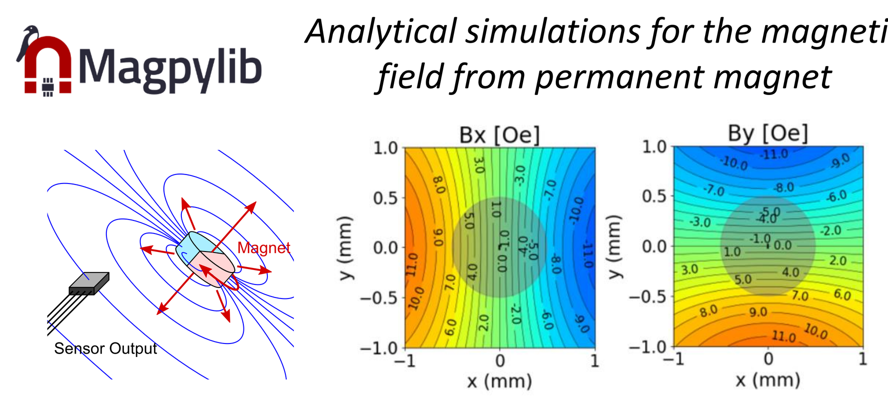
The response is linearized

Stripe magnetic properties (and therefore AMR response) can be tuned with geometry.

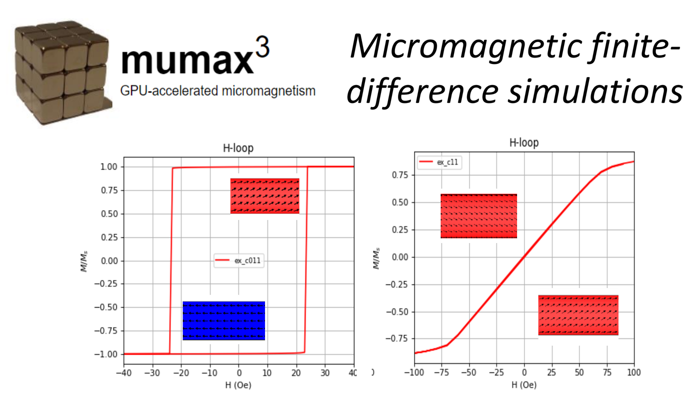


Magnetic microsystem design

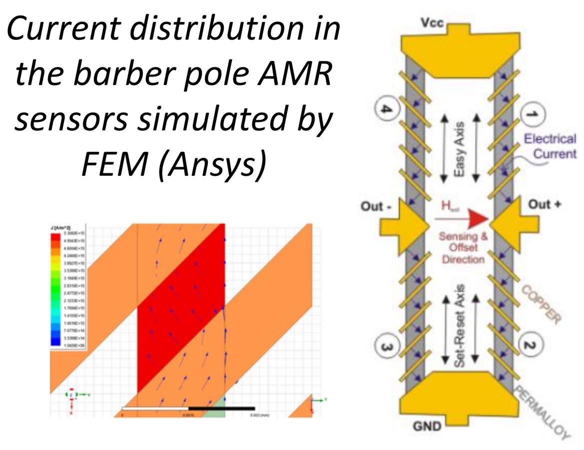
System design combines the functionalities of multiple simulation tools.



Analytical simulations for the magnetic field from permanent magnet

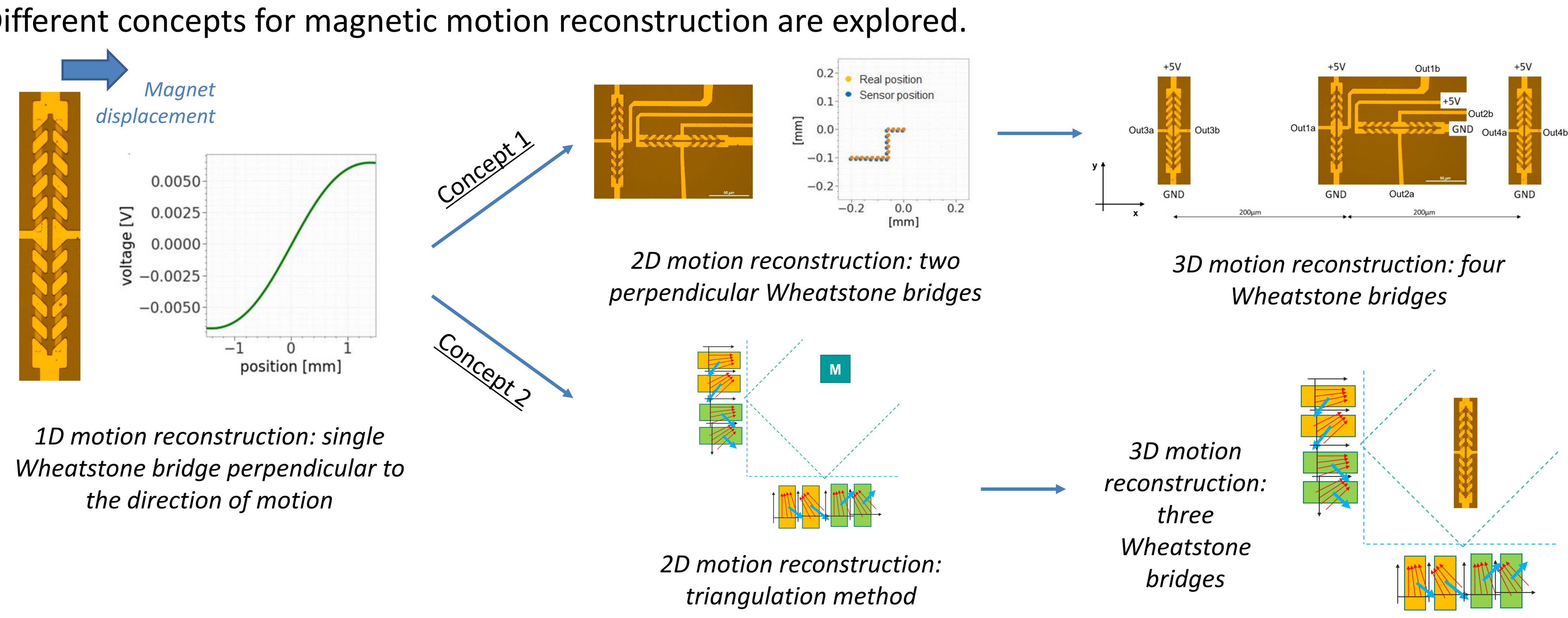


Micromagnetic finite-difference simulations



Current distribution in the barber pole AMR sensors simulated by FEM (Ansys)

Different concepts for magnetic motion reconstruction are explored.



1D motion reconstruction: single Wheatstone bridge perpendicular to the direction of motion

2D motion reconstruction: two perpendicular Wheatstone bridges

3D motion reconstruction: four Wheatstone bridges

2D motion reconstruction: triangulation method

3D motion reconstruction: three Wheatstone bridges

AMR fabrication

AMR sensor fabrication via e-beam evaporation and laser lithography.

Direct Write Lithography Heidelberg DWL66+

Thin Film Deposition Leybold UNIVEX 900

SEM/EDX/FIB/EBL FEI Helios G4 UC

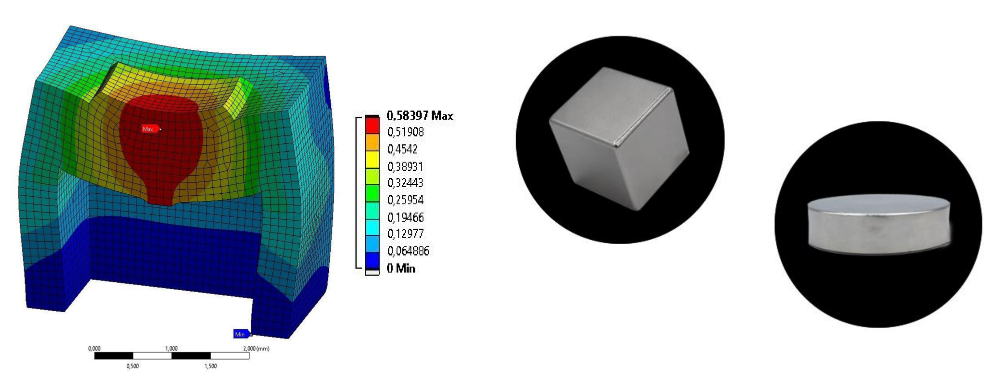
Conclusions

The concept presented here holds potential for the realization of a wide spectrum of easy-to-fabricate, miniaturized and low-cost sensors (e.g., tactile, pressure, flow, acceleration, etc.), suitable for probing a broad variety of physical observables and for integration into microscale devices.

Magnet integration concepts

First approach

- Deformable membrane made of flexible polymer (e.g., PDMS)
- Direct integration of sub-mm commercial permanent magnets into the membrane
- Assembly of deformable membrane and magnetic sensor into a single device

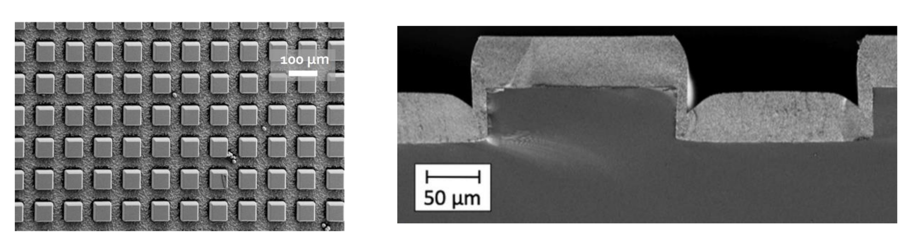


Limitations

- Large fabrication tolerances
- Poor control over permanent magnet properties (size, magnetization)

Second approach

- Integration of microfabricated permanent magnets into the deformable membrane

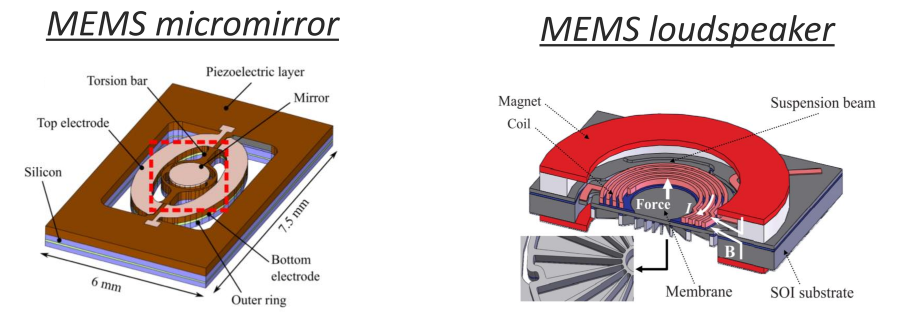


Collaboration with French start-up (MicroMagFab, Grenoble)

Advantages

- Fine control over permanent magnet properties
- Low fabrication tolerances
- Scalability potential
- Approach has potential for extension to several MEMS systems

MEMS micromirror | *MEMS loudspeaker*



A. Piot et al, *Journal of Microelectromechanical Systems* **30** (2021)

I. Shahosseini et al, *IEEE Sensors Journal* **13** (2013)