AMR sensor array design for permanent magnet 3D motion tracking

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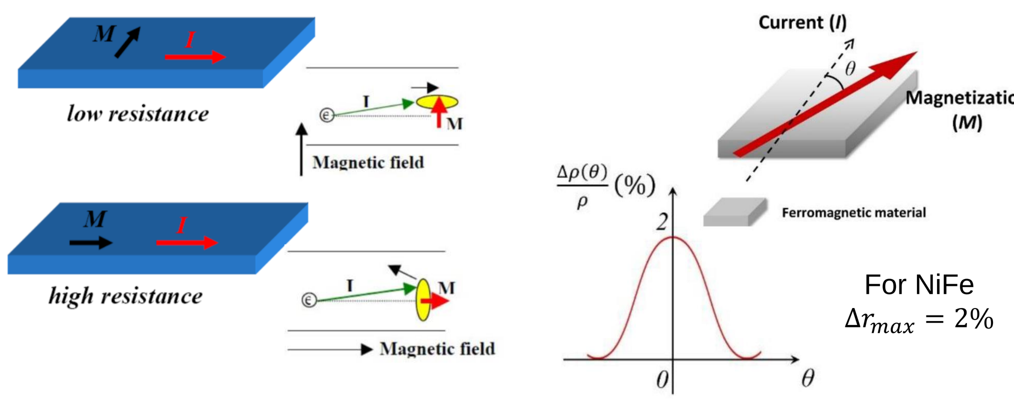
Introduction

Magnetic field sensors are essential components of several industrial, biomedical and consumer electronics applications. Sensors based on the anisotropic magnetoresistance (AMR) effect are particularly attractive due to their relatively simple and cheap fabrication process, which makes them easily prone to miniaturization thus allowing to achieve high sensitivity at low cost in a compact footprint. Here, we combine numerical methods and analytical calculations to design AMR sensor arrays capable of tracking the 3D motion of a permanent magnet.

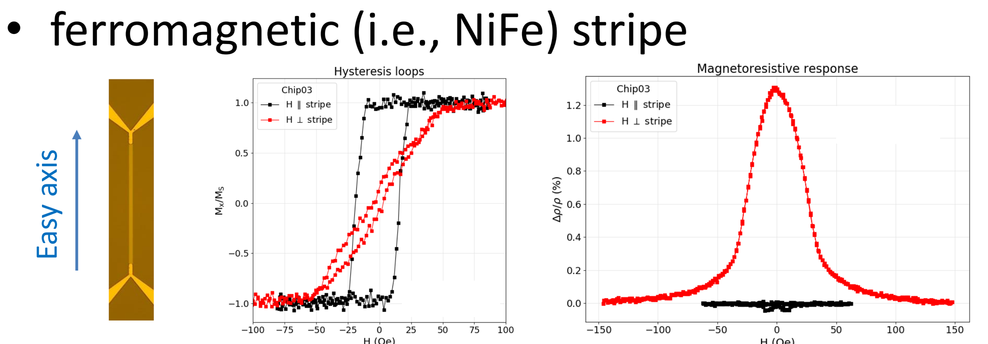
AMR sensors

Resistance change in a ferromagnetic material according to the relative orientation of current and magnetization: $R = R_0(1 + \Delta r_{max} \cos^2 \theta)$

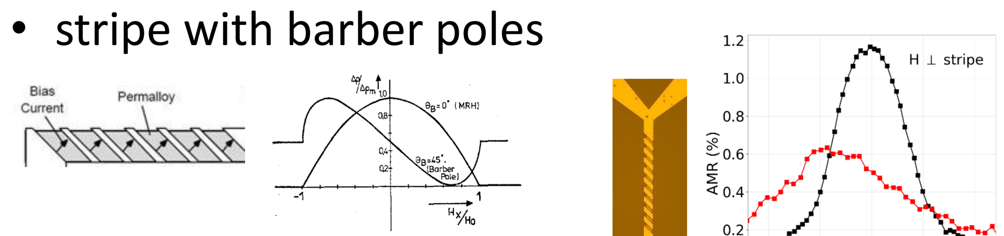


Sensor response:

- ferromagnetic (i.e., NiFe) stripe

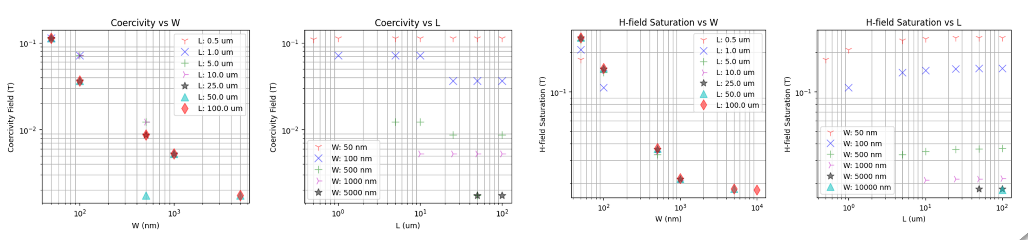


- stripe with barber poles



Current is forced at 45° with respect to the easy axis and the AMR response is linearized

Stripe magnetic properties (and therefore AMR response) can be tuned by varying the geometry.



AMR sensor fabrication

AMR sensor patterning via laser lithography and material deposition via e-beam evaporation.

Direct Write Lithography Heidelberg DWL66+

Thin Film Deposition Leybold UNIVEX 900

SEM/EDX/FIB/EBL FEI Helios G4 UC

Conclusions

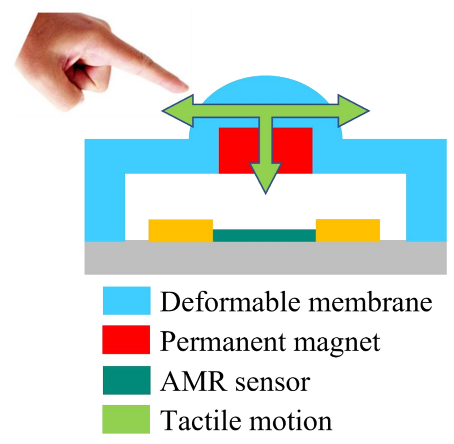
These results demonstrate the possibility to track the 3D movement of a permanent magnet via properly designed and monolithically fabricated planar arrays of AMR sensors.

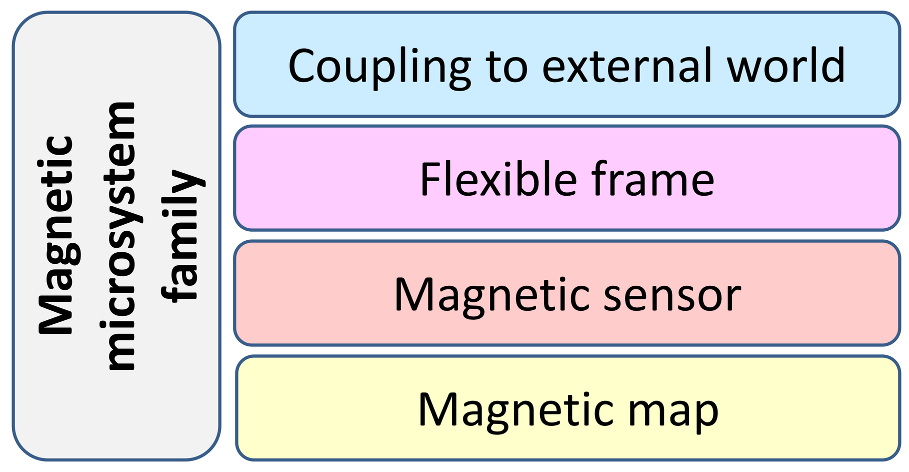
The versatility of the concept presented here holds potential for the realization of a broad spectrum of easy-to-fabricate, low-cost and miniaturized sensors suitable for probing a wide variety of physical observables.

Integration of magnets and magnetic sensors into microsystems

The basic structure of this class of microsystems consists of two main parts: (i) an array of AMR sensors and (ii) a permanent magnet 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.

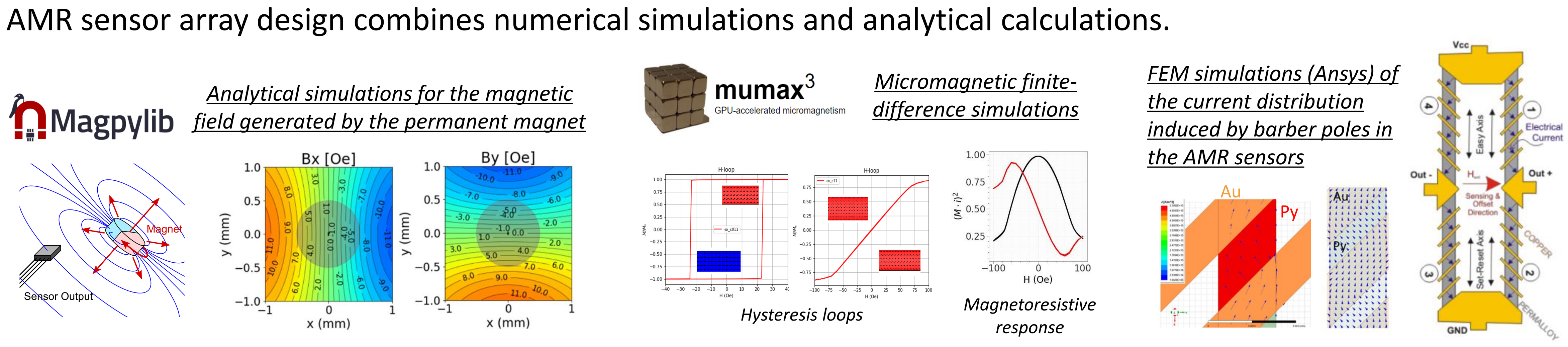
The concept can be applied for a wide spectrum of sensing solutions: tactile and pressure sensors, accelerometers, (micro-)flow sensors, etc.



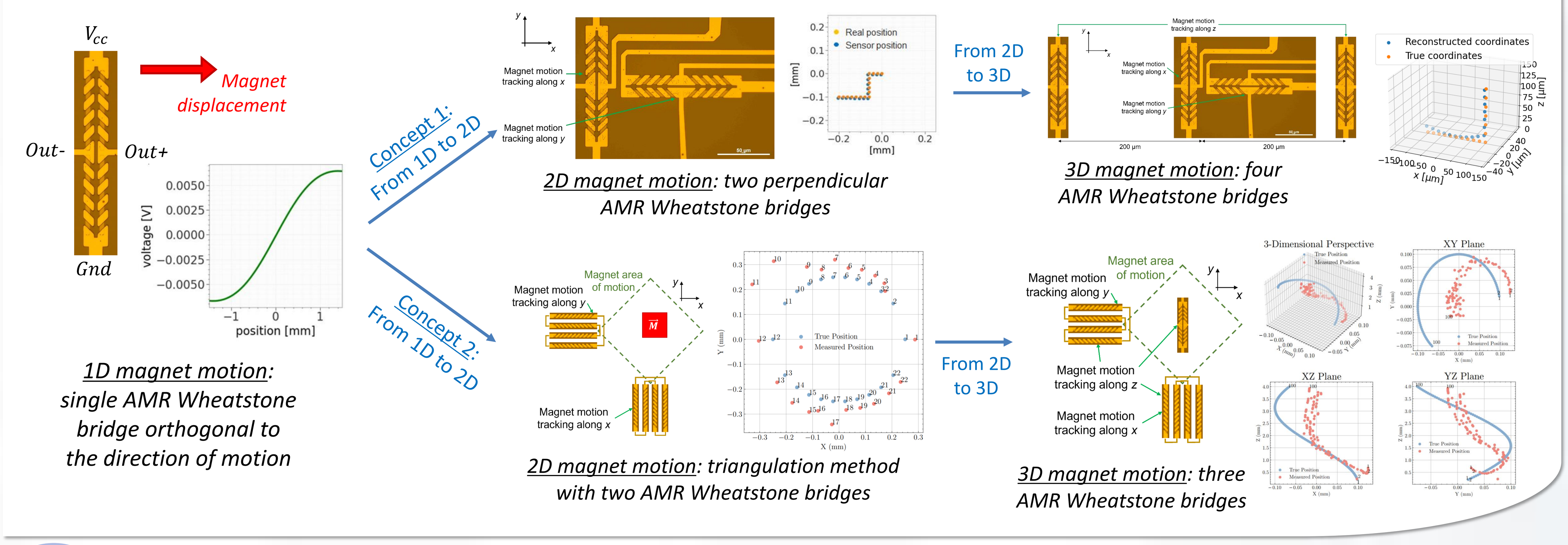


Magnetic microsystem design

AMR sensor array design combines numerical simulations and analytical calculations.



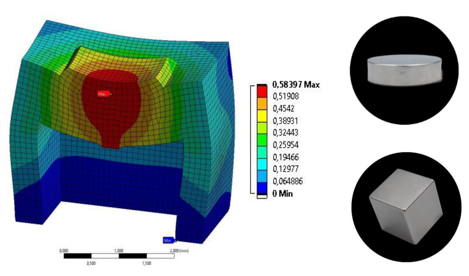
Different AMR sensor array layout solutions for 1D, 2D and 3D magnet motion reconstruction are explored.



Magnet integration concepts

First approach

- Flexible polymer (e.g., PDMS) membrane
- Integration of sub-mm off-the-shelf permanent magnets into the membrane
- Assembly of deformable membrane and AMR magnetic sensor into a single device

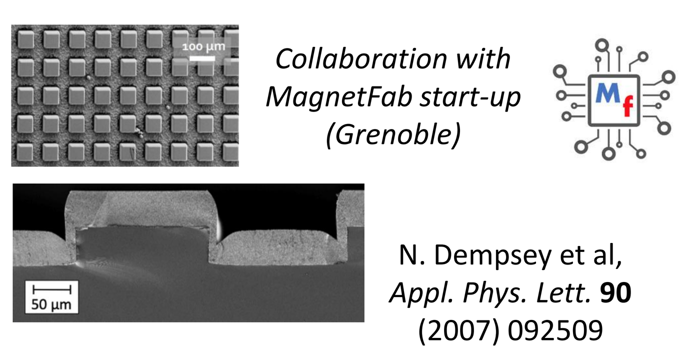


Limitations

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

Second approach

- Integration of microfabricated permanent magnets into the deformable membrane



Collaboration with MagnetFab start-up (Grenoble)

N. Dempsey et al, *Appl. Phys. Lett.* **90** (2007) 092509

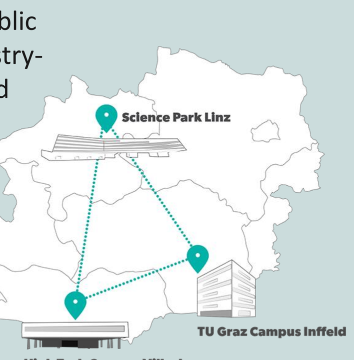
Advantages

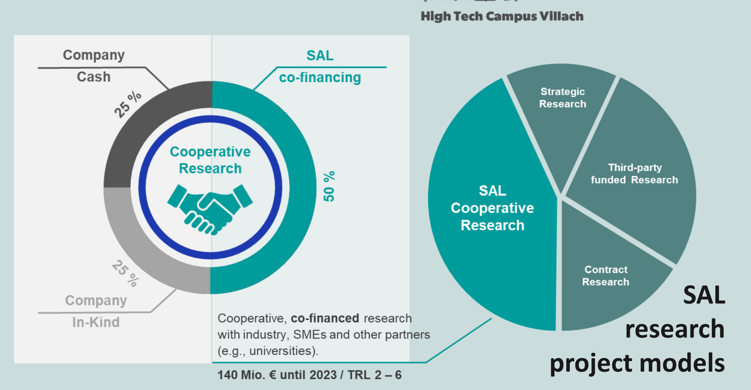
- Fine control of magnet properties
- Low fabrication tolerances
- Scalability potential
- Suitable for extension to several other MEMS systems

Silicon Austria Labs (SAL)

Silicon Austria Labs (SAL) is a public research center performing industry-oriented R&D on electronic-based systems and trying to build fundamental research into applications.

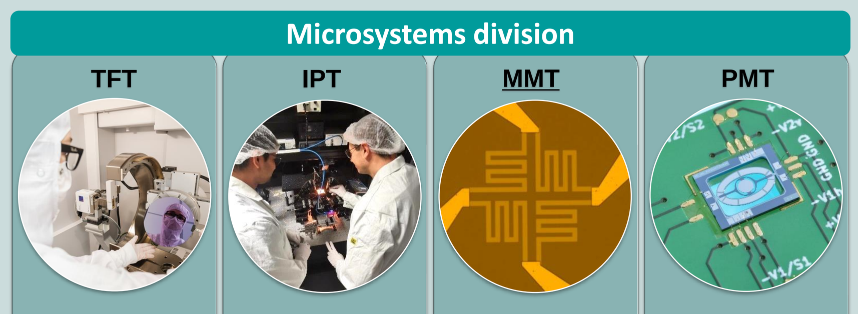
3 locations: Graz, Villach, Linz





6 research divisions: Microsystems, Sensor Systems, Power Electronics, RF Systems, Embedded Systems, System Integration Technologies

Microsystems division



TFT	IPT	MMT	PMT
Thin Film Technologies	Integrated Photonics Technologies	Magnetic Microsystem Technologies	Piezoelectric Microsystem Technologies
Emerging materials for advanced semiconductor and microelectronic industries	Design, modelling and fabrication of integrated photonics, Photonic MEMS and meta-optics for miniature sensing and imaging systems	Analytical modeling, combination of micro & macro magnetic simulations, AMR sensor design and fabrication	RF filters, SAW/BAW, piezo MEMS, PMUTs, MOEMS, micromirrors, microphones, microspeakers,...

Sinergy with scientific and industrial partners

MMT research unit

Magnetic position systems
- ✓ Theory & numerical simulations
- ✓ System design, fab & test

Magnetism and Sensors
- ✓ Custom sensor design & fab
- ✓ MEMS integration

Industrial position systems		Micromagnetic Applications
Magnetic System Simulation	Magnetic Gas Sensing	Magnetoresistive Sensors
Magnetic Encoder Systems	Micromagnetic Simulations	EMR Devices
Magnetic Position Systems	Thick SmCo Layers	Integration into MEMS Structures
Python Package Development	Custom Simulation	Integrated Current Sensing