Development of innovative magnetic sensors with tuning features for a wide operative range

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Research Topic

The goal of this research activity consists in the development of integrated magnetic field sensors with a wide and "tunable" operating range and a constant resolution throughout the whole operating range. Two applications are planned for the sensors to be developed:

- ➢ detection of parking slot occupancy through the sensing of the alterations induced to the local strength of the geomagnetic field due to the presence of metallic targets such as cars or trucks.
- ➢ mapping of the magnetic field dispersed in a particle accelerator.

The detection range is the following:

[1µT-2T]

This Ph.D. project is focused BOTH toward industrial and scientific applications, it is expected to develop and test the sensor prototypes both at the research company and research entity involved, each for its own context.

low magnetic field → PARADOX ENGINEERING

high magnetic field → CERN

The Lorentz force magnetometer: Working Principle

This typology of sensor is based on the interaction between an unknown external magnetic field to be estimated and a known current generated into an U-shaped cantilever beam. If the current I is driven into the cantilever, the interaction between this current and the magnetic field Bx produces the Lorentz force, FL , whose amplitude is:

$$F_L = I \cdot B_x \cdot L$$

where L quantity is the length of cantilever subjected to perpendicular B_x. The force produced will be oriented perpendicularly to the cantilever.

The cantilever is deflected due to the Lorentz force applied to its free end. In literature there are several papers based on U-shaped cantilevers and the most common technology is CMOS technology. However, the applicative ranges vary into the interval [40µT-2mT] . In order to determine a wider operative range specific parameters, like mechanical stiffness, suitable technology, magnetostrictive materials and readout strategies have to be considered.

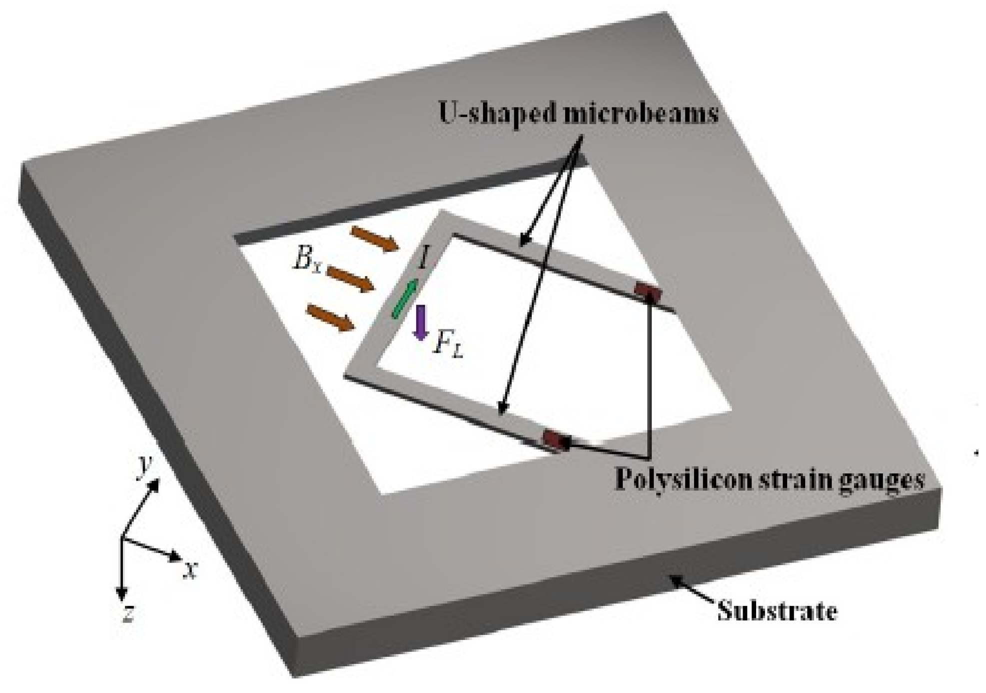


Fig. 1 : Schematic representation

MEMS Technology: PiezoMUMPs

Among others, the microfabrication technology that is under consideration for fabricating the sensor prototype is PiezoMUMPs technology (a cross sectional view is presented in Fig. 2) where an AlN (Aluminum Nitride) piezoelectric layer is used to generate an electric output: this aspect represents the most important advantage in this process, because an electric signal is directly available in the output of the sensor. In this manner the sensor output isn't correlated to variation of resistance (resistive output) or capacitance (capacitive output).

The embedding of piezoelectric materials allows for considering interesting and appealing extensions of the transducers functionalities toward self generating transducers and energy harvesting.

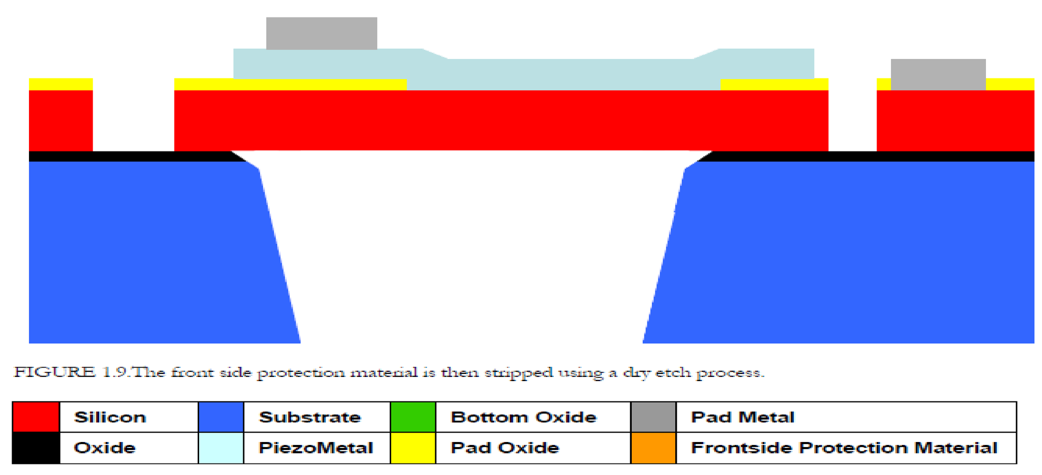
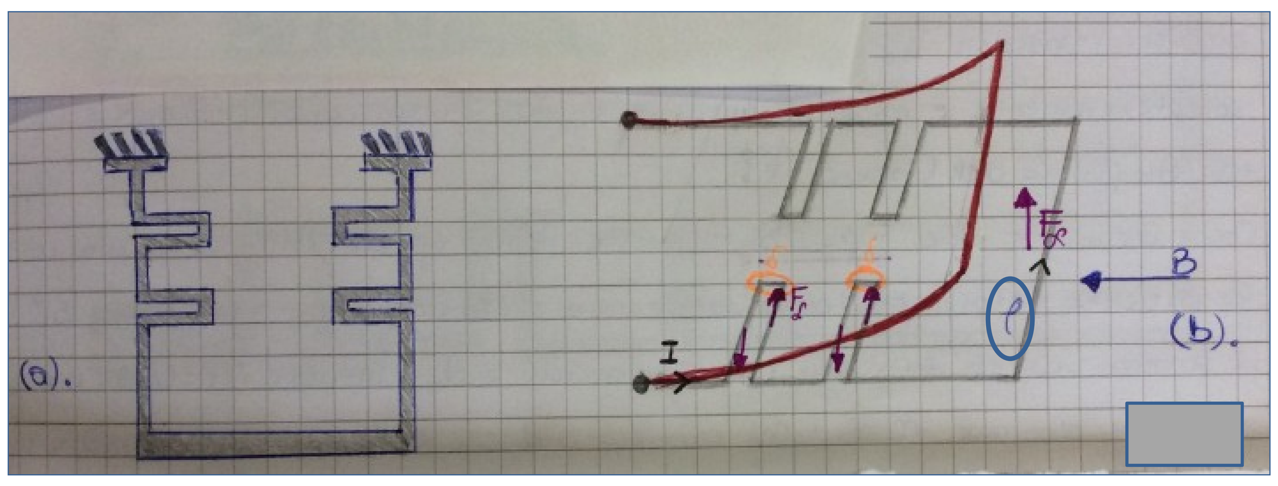


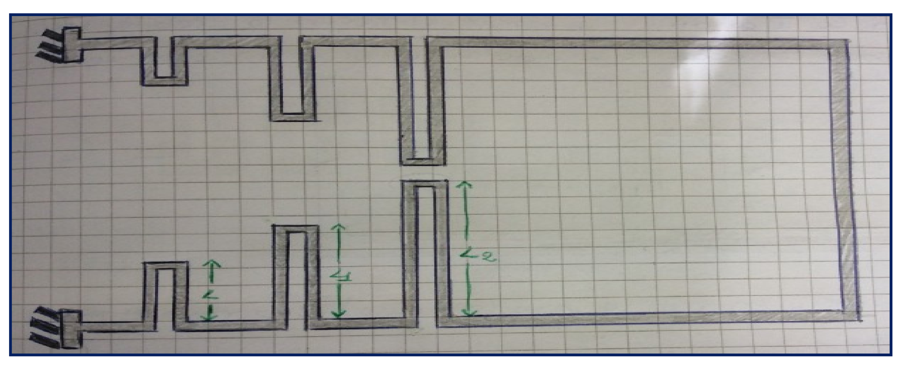
Fig.2: Cross sectional view

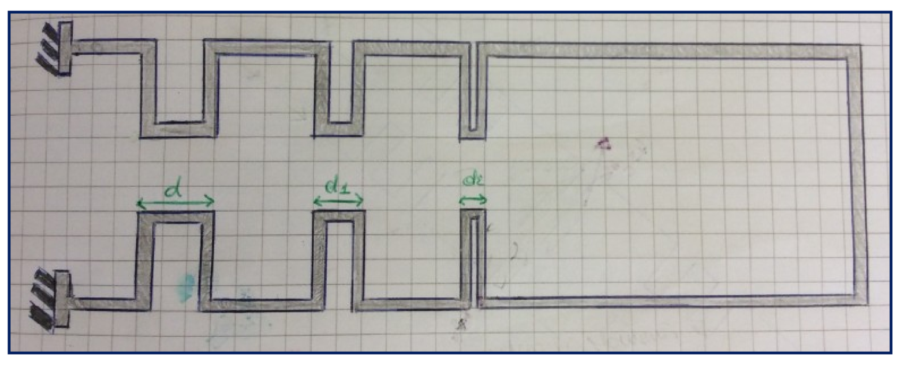
Ongoing activity: Study of Sensor Topologies

The sensor is actuated by the Lorentz Force and its deflection is increased by the presence of folded beams, which provide a contribution in terms of elastic constant (k) and total Lorentz force: when there's a driving current, I, in the device and an external magnetic field is present (B), the Lorentz Force acts on the side "I" and also on the arms of the springs parallel to "I"; furthermore, the presence of the springs affects the total stiffness.

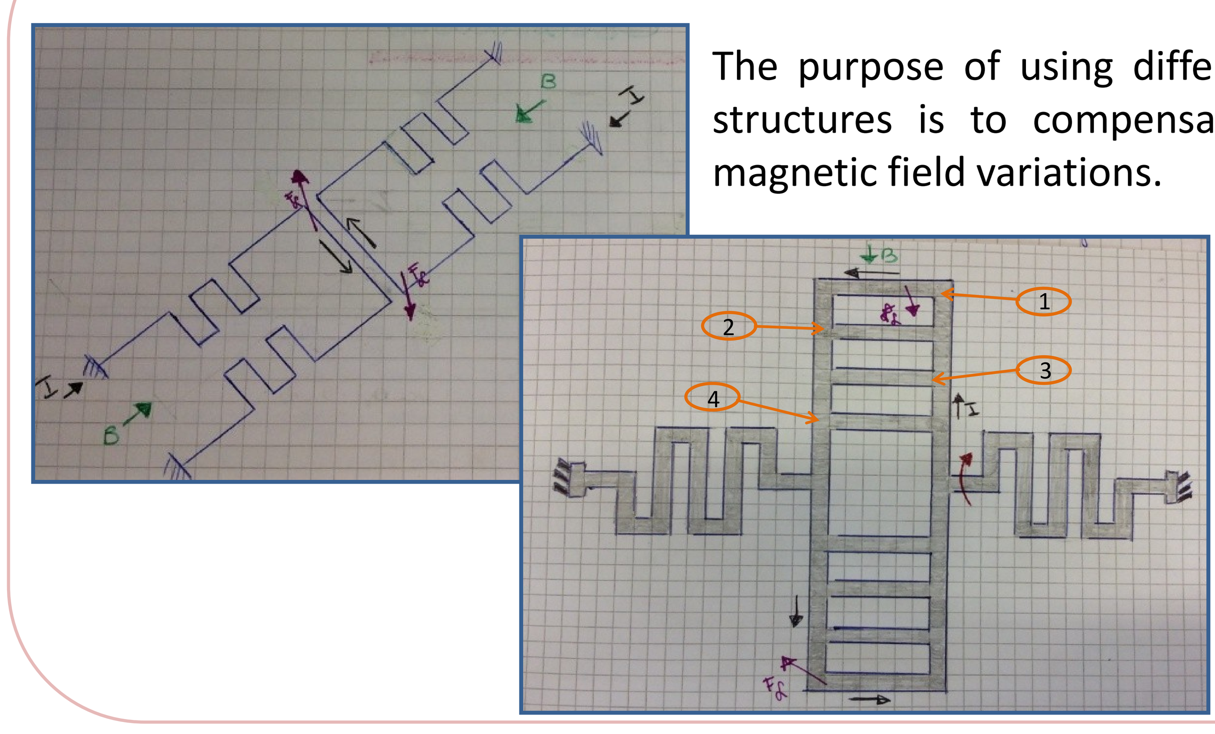


It's possible to consider a new device varying length or width of the folded beams. The idea is to evaluate the performances of two structures in terms of elastic constant and Lorentz Force, F_L, through the MATLAB Toolbox, in order to estimate their characteristics and then to select the best.





Differential structures

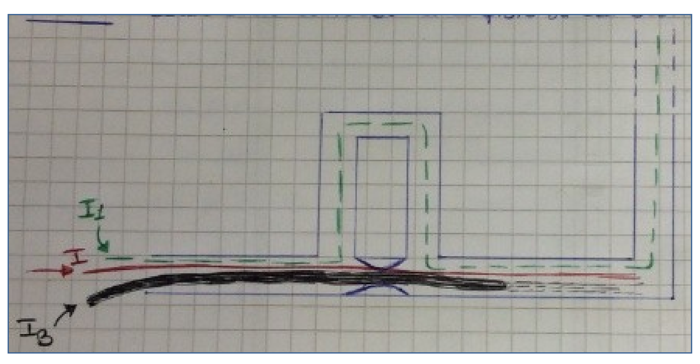


The purpose of using differential structures is to compensate for magnetic field variations.

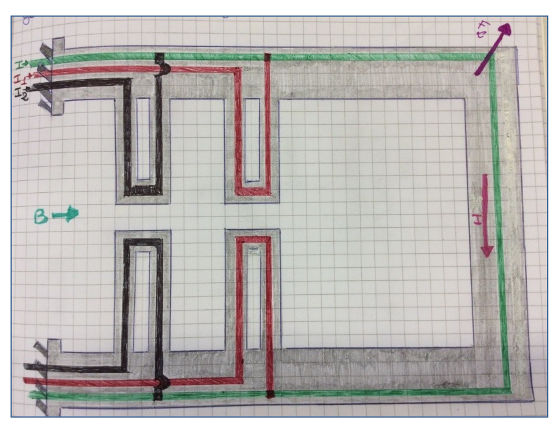
Tunable device

The underlying idea is to produce a device that can work in a very wide range; therefore, it's important that the springs are activated in function of the external magnetic field. Two possible and different solutions to obtain this result are investigated at the moment.

IRREVERSIBLE process



REVERSIBLE process



Further Activities

At the moment, the MATLAB Toolbox is used to analyze static and dynamic model for each topology of device (single and differential structure) in order to establish the best in terms of performances.