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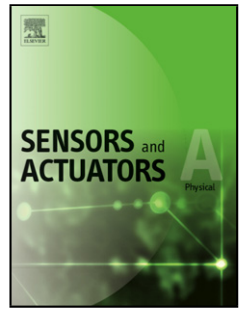

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A magnetostrictive biased magnetic field sensor with geometrically controlled full-scale range

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Abstract

A *magnetic field sensor* prototype is developed and tested in this work. The device exploits a *Galfenol* rod, i.e. a giant magnetostrictive *Iron-Gallium* alloy, integrated with a *Fiber Bragg Grating*. In particular, the full-scale range of the sensor can be modulated through the exploitation of the geometrically dependent effect of the *demagnetizing field*. Indeed, it pushes toward higher fields the magnetic saturation by producing a sort of magnetic shield in the material. As a consequence, the geometrical viewpoint is included into the frame of the entire design process, with the aim of investigate how it influences the detectability range and the performance of the sensor. Furthermore, a permanent magnet system providing a *DC bias* magnetic field has been designed and exploited to allow the device to be able to measure both negative and positive magnetic fields.

Keywords: Magnetic field sensors, Magnetostrictive materials, Fiber Bragg Gratings, Harsh environments, Demagnetizing field effect

1. Introduction

Magnetic field sensing belongs to a research area of a wide and constantly increasing interest. Indeed, it is well known the vastness and the variety of applications which make use of magnetic field sensors. Furthermore, the number of these applications is in a direct proportional link with the technological development. Of course, a lot of solutions can be exploited, depending on the particular application. For example, recent studies investigates the possibility to exploit *magnetoelectric heterostructures* to develop very high sensitive sensors, [1–4]. Further studies in this direction show that the usage of *ferrofluids* as active material could represent a convenient approach, [5–7]. Conversely, devices able to operate in extreme conditions, e.g. very high or low temperature and pressures, high vacuum or radiations, are requested for applications dealing with aerospace and nuclear fusion, [8]. For this reason, a great effort has been made in the last decade with the aim to develop magnetic field sensors able to work in *harsh environments*. A suitable approach seems to consist into the integration of *optical fiber sensors* with *smart materials*, because of the advantages of both technologies. In particular, optical fiber is characterized by small size, light weight, high sensitivity, high-temperature performance and it allows the sensor to be completely insensitive to electromagnetic interference, [9]. On the other hand, smart materials have the advantage to be able to operate in a wide range of temperature and pressures, [10–12]. Particularly, the usage of materials with huge *magneto-elastic coupling*, such as *magnetostrictives*, is widely investigated. For example, in [13] and [14] a *Tb-Dy-Fe* bar, is coupled to a *Fiber Bragg Grating* (*FBG*) and a *Long-Period Grating* (*LPG*) optical fiber sensor, respectively. Conversely, in [15] a *Phase-shifted Fiber Bragg Grating* is used. However, *Tb-Dy-Fe* alloys showed some drawback, e.g. brittleness, scarce workability and, further, high hysteresis phenomena, that restricted the application area of the sensor. The latter required, as discussed in [13], a complex hysteresis compensation algorithm that, even if effective for field reconstruction, required the design of a complex system for managing such complex behavior in real time. The employment of other materials, such as *Fe-Ga* alloy (*Galfenol*), allowed to overtake the mechanical limitations and hysteresis phenomena, [16], at the cost, however, of a wide reduction of the detection field range.
An effort to address this limiting issue has been dis-

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