STRAIN SENSORS BASED ON FIBER BRAGG GRATINGS FOR VOLCANO MONITORING

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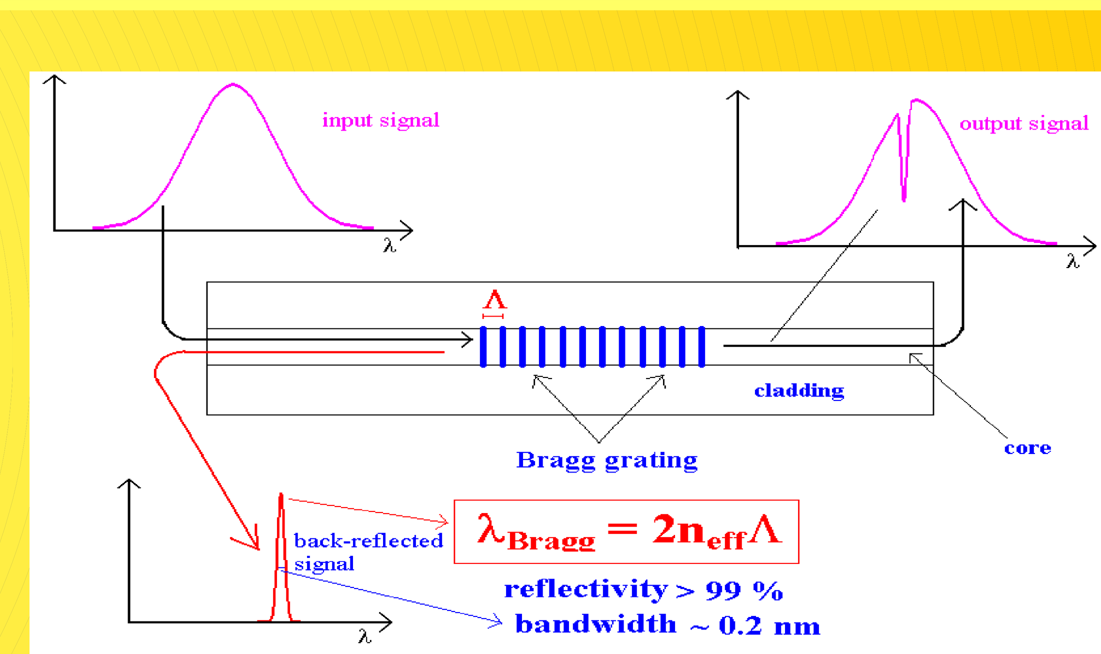
INTRODUCTION

Fiber Bragg Grating Sensors have emerged as a cost-effective tool for monitoring in civil engineering. FBG sensors are also very promising for stress-strain monitoring in geophysics, although little literature exists on this.

A Fiber Bragg Grating (FBG) is a periodic perturbation of the core refractive index of a monomode optical fiber. When the radiation generated by a broad source is injected into the fiber and interacts with the grating, only the wavelength in a "narrow band" (~0.2 nm) can be back-reflected without any perturbation in the other wavelengths. If the grating period is Λ, and the core effective refractive index is n_{eff}, the reflected component can be determinated by:

$$\lambda_{Bragg} = 2n_{eff}\Lambda$$



SINGLE-AXIS FBG STRAIN SENSOR: PRELIMINARY PROTOTYPE

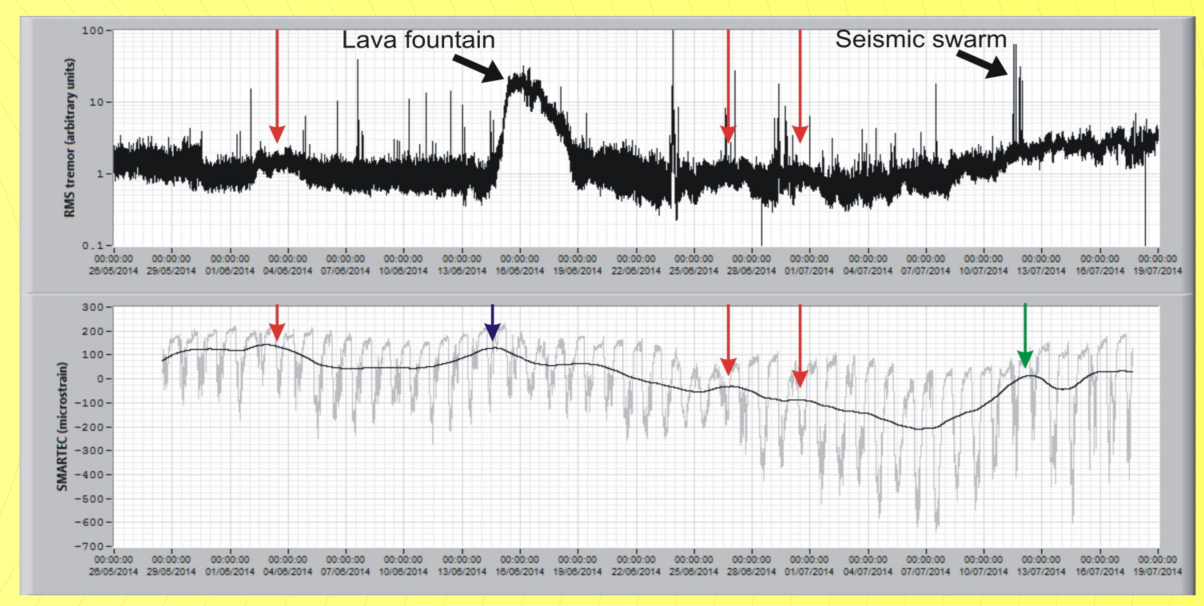
The measurement of crustal deformation through strain sensors is crucial in geophysical applications. Conventional methods (e.g. extensometers installed underground) are expensive and large in size and thus of difficult installation.

Main advantages of FBGs in geophysics:
- the low cost
- the small size
- the easy implementation of large arrays covering a wide frequency range
- the immunity to harsh weather conditions

Within **MedSuv project**[1] we are developing a prototype of FBG strain sensor for volcano monitoring, with a higher resolution and accuracy in static measurements. The system will allow multi-axial strain sensing with special attention to the trade-off between resolution, cost and power consumption.

The preliminary prototype has been tested first in laboratory and then installed across a surface trace of a fracture opened in 1989 eruption on Mt. Etna.

The field test installation was aimed at checking the performances in out-of-the-lab conditions in order to inform the design specifications of the final multi-axis device for volcano monitoring.



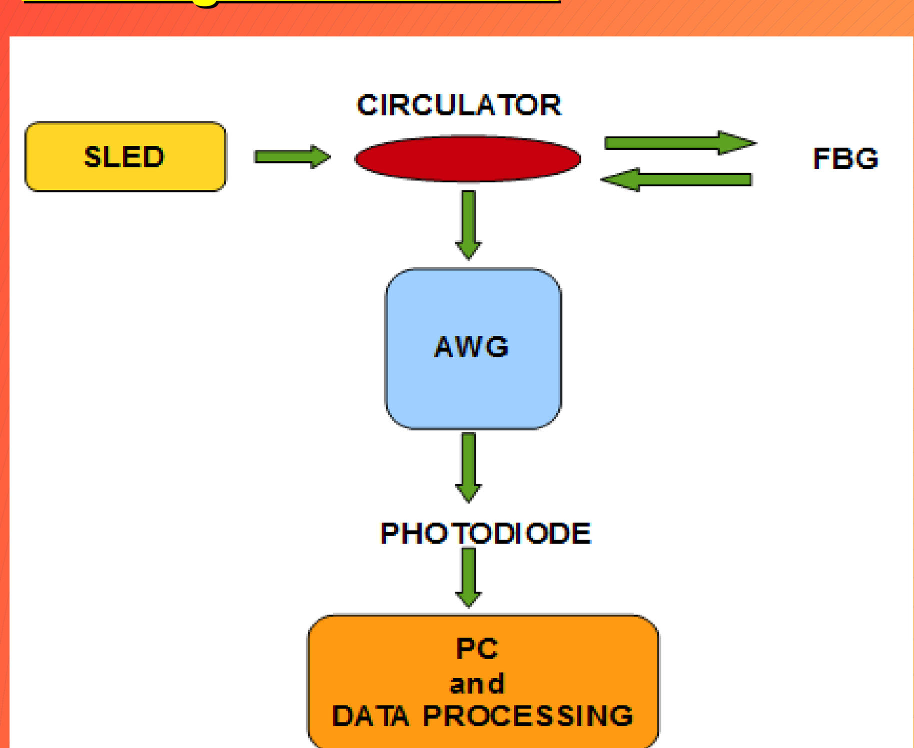
Comparison between data from a Seismic Station at Mt. Etna (ESPC) and data from strain meter placed in a different site: signal from the strain meter shows positive correlation with the volcanic tremor detected by the seismic station.

MULTI-AXIS FBG STRAIN SENSOR

Different interrogation methods can be used for reading out Bragg wavelength shifts experienced by FBGs, from which strain is evaluated. Among the possible methods, the choice of the more suitable interrogation system depends on different factors, since the FBGs can be used to measure static and/or dynamic strain with different ranges, accuracy, sensitivity, number of sensors, complexity and cost.

We propose a **low-cost, compact and high-performance interrogation solution** based on the demultiplexing of an Arrayed Waveguide Grating (AWG).

Interrogation scheme



The FBG is illuminated with a broad-band source (Superluminescent LED); the reflected light from the FBG is sent through an optical circulator to an AWG. Each channel of the AWG is detected by a photodiode and the output signal is processed by a PC.

The shift of the Bragg wavelength can be interrogated by the relative intensity reading of two-adjacent-channels of the AWG.

When a stress is applied, the Bragg wavelength of the FBG sensor will shift to short wavelength or to long wavelength depending on the correspondent strain (constriction or extension). The shifts of Bragg wavelength can be measured by monitoring the power ratio of the AWG, *P(k)* and *P(k+1)*, detected by two photodiodes. The power ratio is expressed in the equation below[2]:

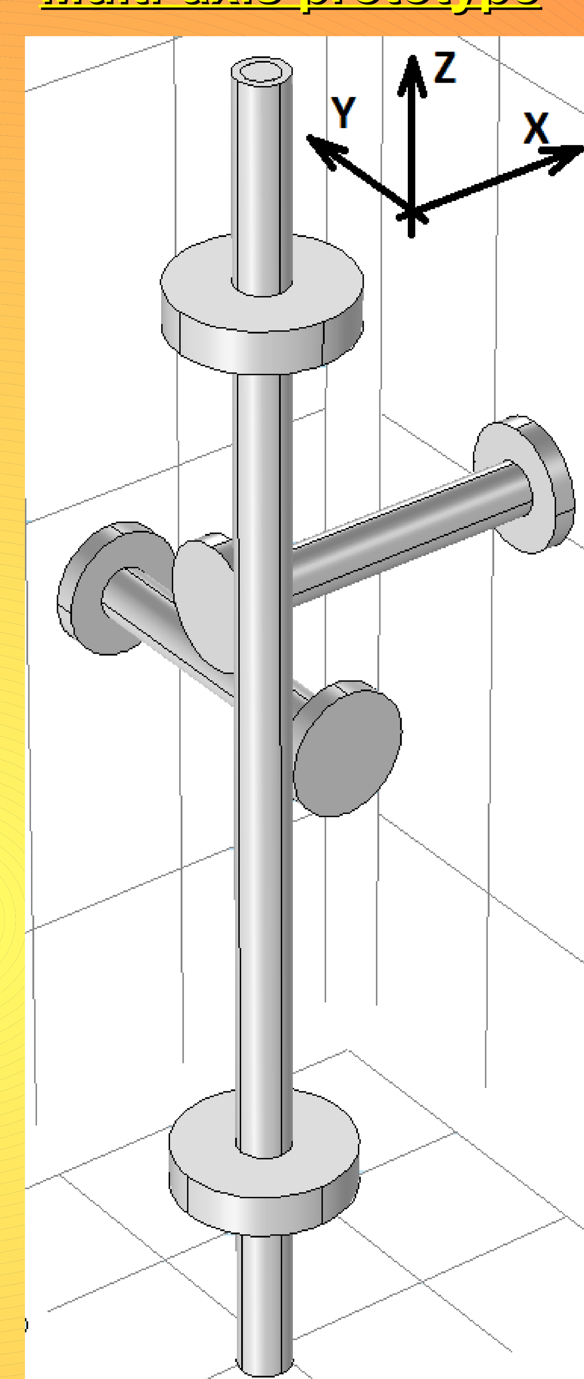
$$S = \frac{P(k+1) - P(k)}{P(k+1) + P(k)}$$

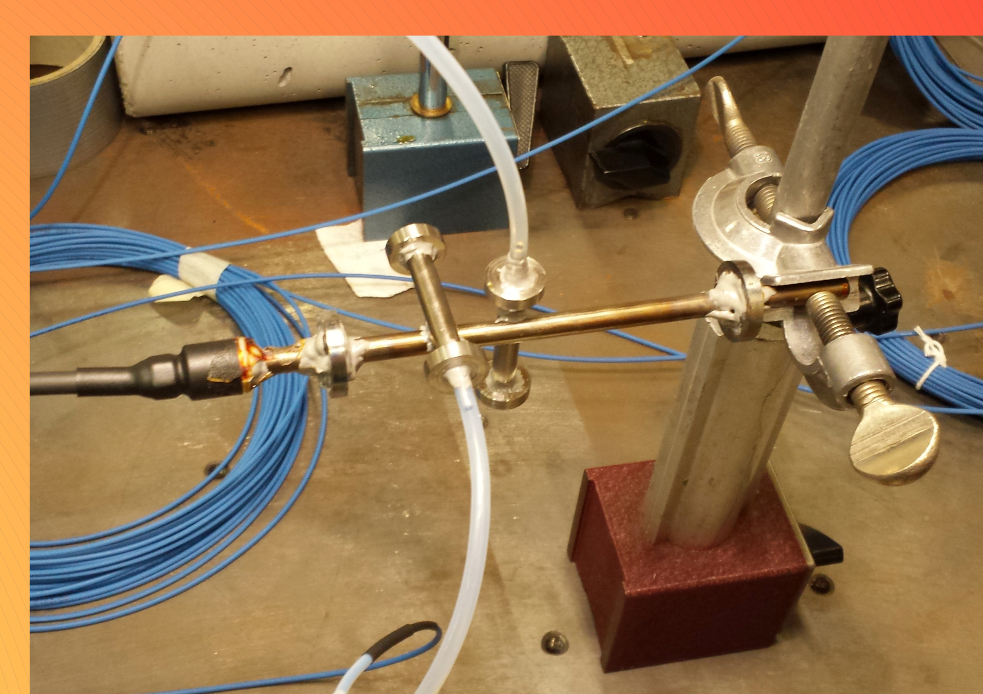
Results from laboratory tests:

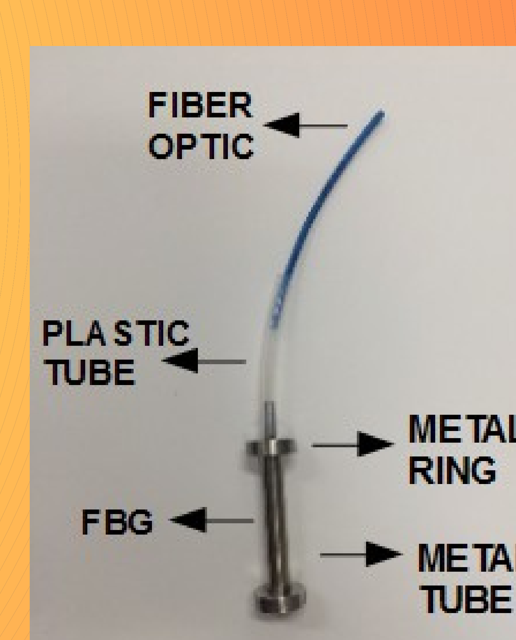
Sensitivity:
According to lab tests we obtained a dynamic range of ~150με and a resolution of ~0.5με.

Thermal drifts:
Temperature can affect the AWG (~10pm/°C), resulting in a shift of the central wavelength and thus compromising the measurement. We thermostatated the AWG and obtained an excursion within a few tens of mK: this solution ensures no variations in the reproducibility in the long period.

Multi-axis prototype







Mechanical design:

We deal with a **borehole strain meter** able to detect strain changes at volcanic areas.

The bore hole has a cylindrical diameter of 10cm, where the system will be included. For convenience of construction we placed three sensors along x, y, z, fixed in one extremity to let the fiber follow its curve radius.

A temperature sensor has been included, to evaluate temperature effects.

Further lab tests are ongoing; in two months the device will be tested in field on Mt Etna.

1 "The MED-SUV project has received funding from the European Union Seventh Framework Programme (FP7) under Grant agreement n°308665"

2 Hui Su, Xu Guang Huang. "A novel fiber Bragg grating interrogating sensor system based on AWG demultiplexing", *Optics Communications*, **275**, pp. 196-200, (2007).