Giacintec

Mesure, Télémesure, Equipement

Fiber optics discussion

Introduction

Giacintec continued the geotechnics business of Company MCE when MCE went out of business when started in 2006. The target, at that time was mainly sensors and telemetry for nuclear power plants and bridges.

Meeting south Koreans in Paris in 2006 accelerated the process. Giacintec was having expertise in tilts sensors, displacement sensors and telemetry, Korean company GMG was offering beacons using tilt, displacement and telemetry. We naturally became representative of GMG.

2007, Prof Chang visited Paris for meeting with our customers, today called IFSTTAR, CEREMA, EDF, ANDRA, Total and others. At that time, Prof Chang from Kumoh Institute and President of GMG explained he was developing other solutions based on fiber optics and this since 2000.

Giacintec started fiber optics representation based on the fact GMG was developing solutions and fiber lines for geotechnics and was using the data logger systems selected on the market worldwide.

Today we sold solutions or parts of solutions to EDF, Andra, IFSTTAR, CEREMA, Military companies and EGIS.

Background

France does not recognize expertise until testing and validating solutions. French engineers, for fiber optics, are mostly issued from telecom and focuses on data transmission and for measurements on FBG (Bragg networks).

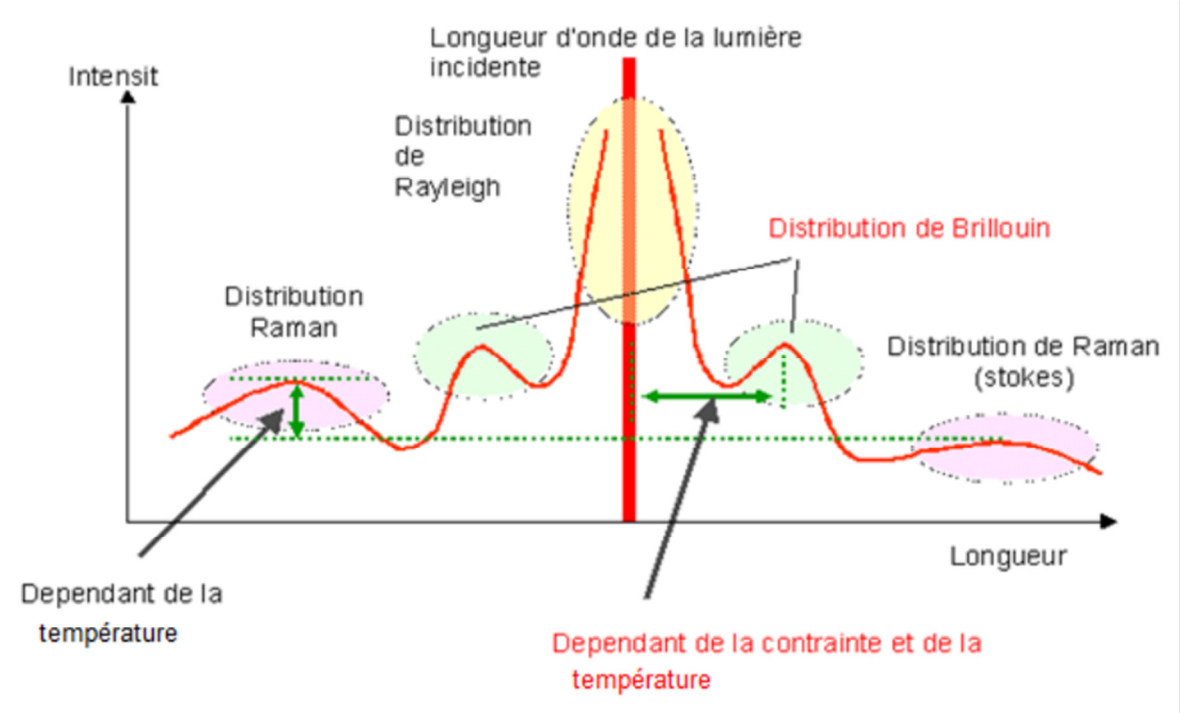
Unfortunately, geotechnics applications are mostly on large surfaces or long linear where FBG does not make any sense. To achieve measurements and as a consequence monitoring, choice remains Brillouin and Raman technics.

What are Brillouin and Raman methods?

When sending a light pulse in a fiber optic, the strength and or temperature, modify the light retro diffusion all along the fiber. The impact between the core in silica and its envelope in different silica can be measured for Brillouin as a frequency shift and for Raman as an amplitude difference. Retro diffusion provides these differences and, knowing the flight speed of the light, gives the location of phenomen**on**.

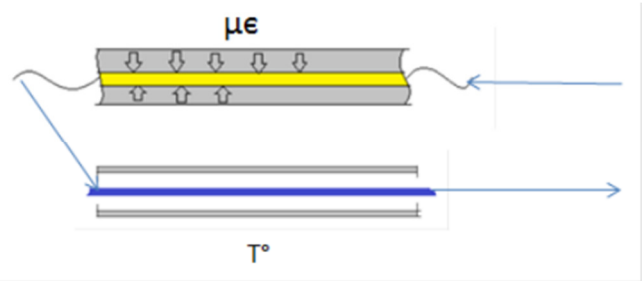
From there, it is possible to measure strength and temperatures all along a fiber optic and to determine where the measurements are performed.

This is basically what can be done but from theory to real world there is a big gap, we will consider what can be done and how.



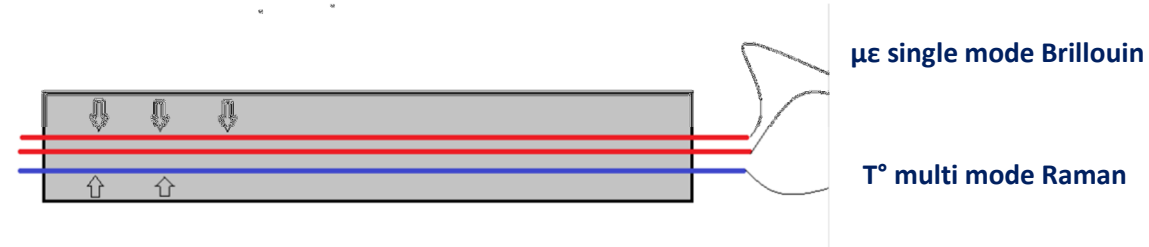
To achieve a consistent measurement needs to be careful. Brillouin method gives both strength and temperature on same fiber optic line. To separate both measurements, one need to use a fiber sensing strength and a fiber not subjected to strength.

Thinking of a loop fiber will allow measuring the way out as strength and way back as temperature.

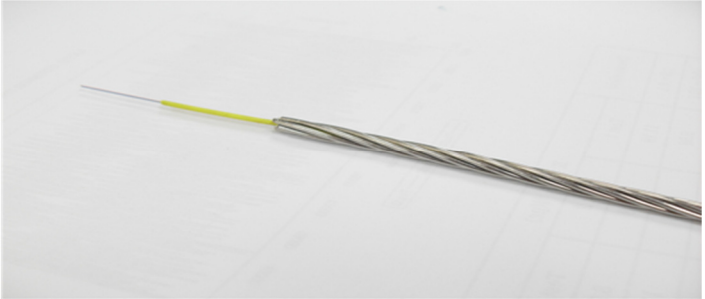


Way out of data logger will sense both temperatures and strength with pre-strength fiber way back the sole temperature with free on strength fiber. It is then possible to compensate strength with temperature data and to output both separately.

Considering Raman, measuring only temperatures, if two data loggers are used, one Brillouin and one Raman, compensation will be made easily.



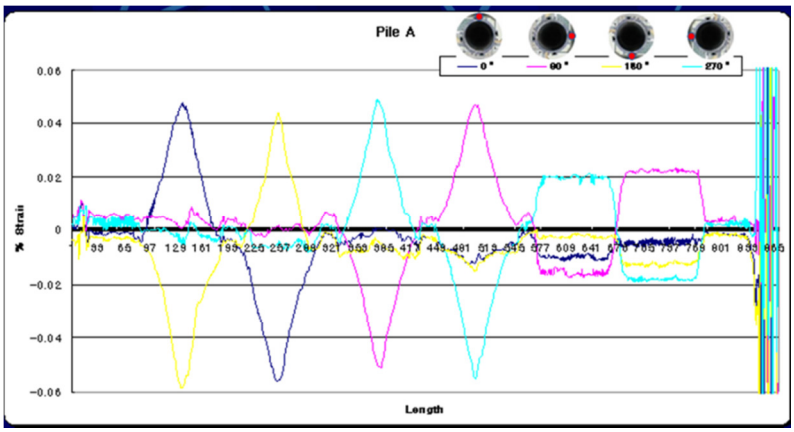
We pointed above pre strength fiber. If the fiber is coated with silicone or other material, in the lab, Lorentzian motion will be clean but not significant. Reason why is to offer a real zero or reference, the fiber must be pre-strength. Sheathing the fiber with a metal structure will offer a real reference, enhancing the sensitivity and avoiding zero fluctuations with whatever strength unexpected and with no relation with measurement that could occur.

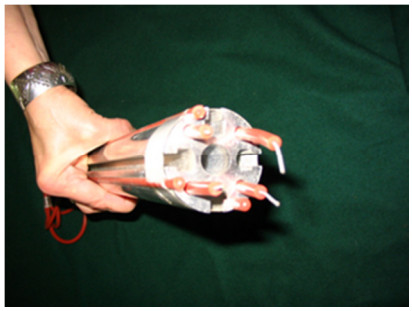


We are nearly ready to perform measurements.

Fibers arrangements

If strength can be measured and located, the application sense of the strength cannot be determines easily except when using 4 lines of fiber.





Measuring 4 lines on a section can provide, if measurements combined, the point of application of the strength. Above motion shows dark blue and yellow in 180 angular degrees opposition giving similar signals with opposite sign when the structure is solicited on the diameter where they are installed and the same for light blue and pink. Combine measurements provides the angle.

One has to understand the spatial resolution for measurements can be very accurate along less than 100 meters of fiber but will sit from 0.5 to 1 meter in case of long length.

If, for some reasons the spatial resolution causes problems, there are solutions. For instance it is not reasonable to imagine measuring temperature for water level measurements with 50 cm accuracy. Even if points in between 50 cm are not lost the accuracy will not fit for such applications. In that case, the solution is to increase the length of fiber in contact with water on small length. Therefore spiraling the fiber will offer a good compromise with a level height resolution of few spires.

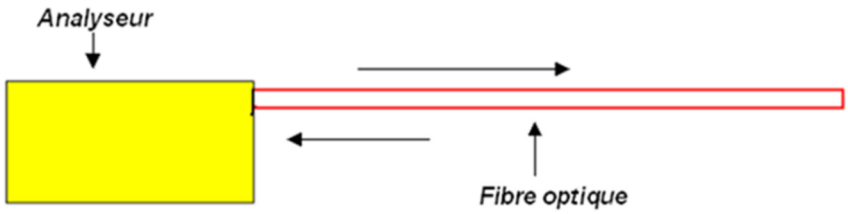
spiral

inclinometer/piezometer

These kinds of arrangements can help achieving a dual sensor with both angle and water level, such an instrument will be called inclinometer/piezometer and will fit in a single pit.

Data loggers

Brillouin method can use different data logger types. **BOTDA** (Brillouin Optical Time Domain Analyses), **BOFDA** (Brillouin Optical Frequency Domain Analyses) that need the fiber to be looped.



The light goes from the data logger and return to data logger. For BOTDA (Time Domain) a pulse goes through the fiber and when back is filtered to get the Brillouin signal eliminating the noise (around 99 %). For BOFDA, the pulse is braked down in several narrow frequencies, when these frequency are received a reverse Fourrier Transform rebuilt the initial pulse but without the huge amount of noise.

These data loggers allow measurements with +/- 2 µm accuracy and spatial resolution of 0.5 meter. This does not mean data in between the 0.5 meter are lost but just the accuracy is not available as specified.

Range for such data loggers is 50 Km.

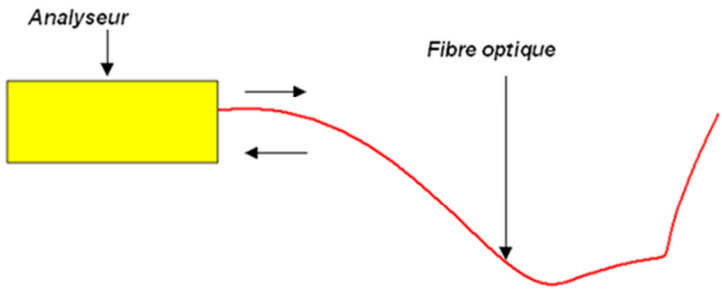
One can understand we prefer BOFDA instead of BOTDA.

Inconvenience is when the fiber line gets cut, the measurements cannot be done anymore and an OTDR instrument is needed to determine where the line is cut.

BOTDR is another type of instrument. The pulse goes all along the fiber and is recovered on the same path with no need of looping the fiber.

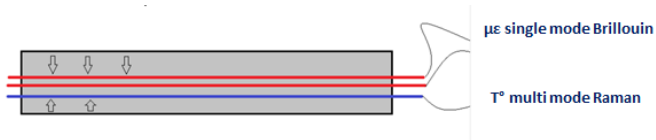
Range is very similar to BOFDA and, today, our partner offers an accuracy of +/- 10 µm and spatial resolution of 1 meter.

Main advantage is this data logger can make quicker measurements and avoid a lot of spurious signal but, moreover, if the fiber optic line is cut, the data logger will tell it and display the cut location.



The choice does not depend upon the price but upon the specific application.

Obviously, discrimination strength from temperatures can be done with Brillouin instruments as long as the strength fiber is strength and the temperature fiber free of strength. Another option for large sites applications is to use both Brillouin and **Raman** data logger. This offers an advantage as Brillouin uses single mode fibers and Raman multimode fibers, today a pre-strength fiber line can be manufactured with both fibers, therefore one line will perform both measurement without the need to de-couple a fiber from strength.



Fibers installations

To measure strength the fiber must sense the strength, this mean the fiber line must me tightly secured to the structure. If this seems easy in ground with grouting, it is lightly different in concrete or metal structures. For concrete, the fiber will be cemented in or on the structure when for metal, the fiber will be pasted with some resin.

G.M.G.'s know how include the experience in real world of implementing the fiber lines and securing these to the structure.

How to install the fiber lines is one of the questions when the other one is where to set these lines. G.M.G. has a very strong knowledge concerning geotechnics and can determine the best location for fiber optics.

Applications

Fiber optics can be used on several types of application : natural sites like slopes, embankments, rock falls ...

A lot of sites are using this technology in order to prevent disasters and this particularly in South Korea where climatology is severe with large temperature differences, heavy rain or heavy snow, earth quacks, floods and others.

Rock fall

Beside natural sites, fiber optics are used for civilian engineering structures including dykes, dams, bridges, tunnels, buildings …

This may be used as well for detecting localization of leakages, icing or intrusion.

Embankments

Dam

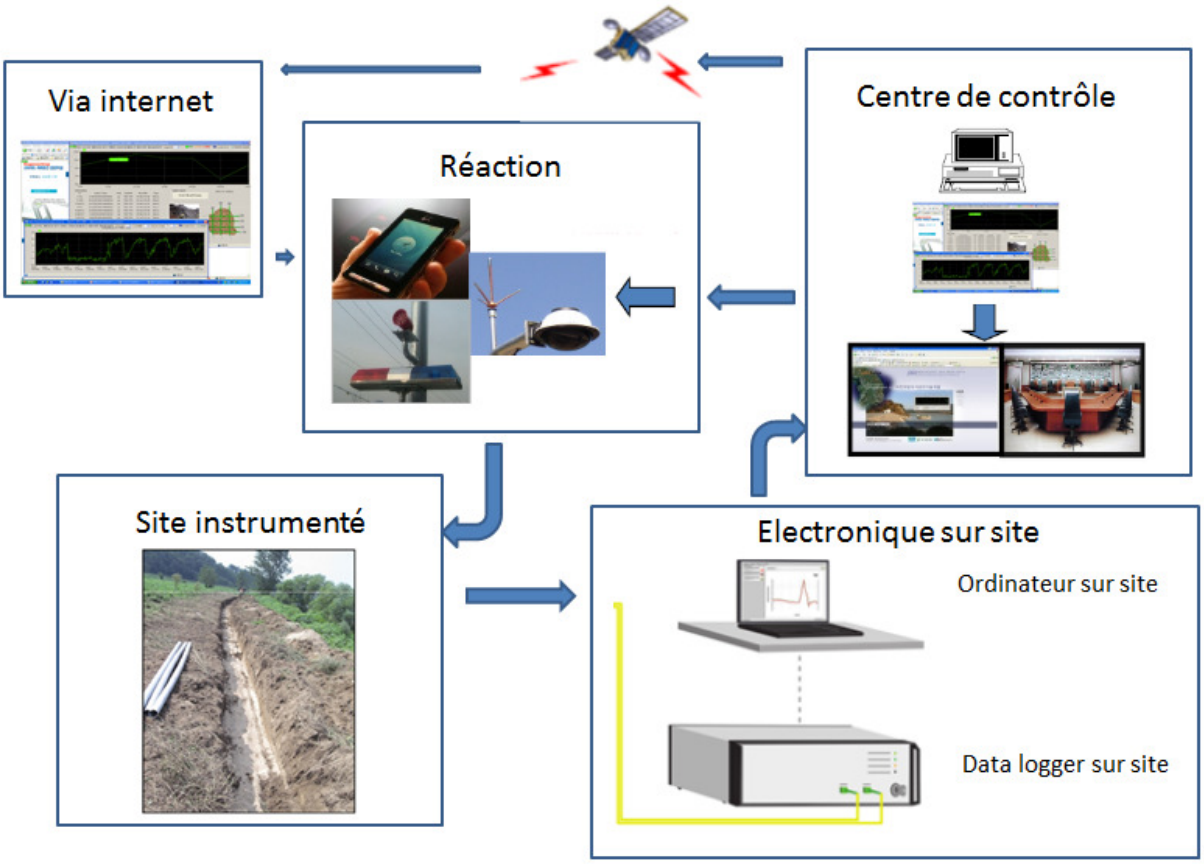
Tunnels

Peers

Dykes

Others

Purpose of monitoring



Purpose of real time monitoring is to prevent disasters. The architecture of the system includes all sensing devices including fiber optics on the site, electronics installed on the site as well with data acquisition for usual sensors and data logger for fiber optics. A concern is to get a communication link in between the site and control center, the link must be two ways and able to process, therefore a computer must be available on site. Communication can be performed via regular telephone links or fiber optics or radio or GSM. Partly processed data may be used from this computer to warn operators including rescue people if needed, the data is then sent to a control room where decisions can be made for alarms of different kinds light, sound, gates and much more. The control room can control as well cameras if existing on site to view directly what happen. System can send SMS and or MMS, phone alerts and others. In the same time, it is possible to set a control board on the web with limited or full access. The internet access helps experts to understand, wherever they are in the world, what is happening on site.

The process of implementing a damage detection and characterization strategy for engineering structures is referred to as structural health monitoring (SHM). Here damage is defined as changes to the material and/or geometric properties of a structural system, including changes to the boundary conditions and system connectivity, which adversely affect the system's performance. The SHM process involves the observation of a system over time using periodically sampled dynamic response measurements from an array of sensors, the extraction of damage-sensitive features from these measurements, and the statistical analysis of these features to determine the current state of system health. For long term SHM, the output of this process is periodically updated information regarding the ability of the structure to perform its intended function in light of the inevitable aging and

degradation resulting from operational environments. After extreme events, such as earthquakes or blast loading, SHM is used for rapid condition screening and aims to provide, in near real time, reliable information regarding the integrity of the structure.

Conclusions

An array of sensors is just what does fiber optics, on a single line of fiber a sensor is available each 50 centimeter or one meter. A data logger can handle several lines, each with maximum length of 50 Kilometer, an 8 channel data logger can manage 800 000 sensors without voltage supply or interferences and this over years and years.

Even if data loggers improve in the future, even if software gets better, main cost of the instrumentation stays in fiber optics implementations and this will not change much.

As a consequence, fiber optics real time monitoring is the best answer for structural health monitoring for short terms and long terms surveys.

The sole question is where the expertise stays? Obviously G.M.G. has a strong expertise with several patents and feedback from applications. Among specialists throughout the world G.M.G. is producing the best results. The reason is they are not trying to supply data logger and makes the choice on what is available, they have a network of scientists working and implementing, for instance, erosion detection and locations in dykes, they have resources to design, test and apply technologies to the real world.

Today, we can offer the best real time monitoring solution.

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