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Distributed Sensing by Using the Brillouin Scattering Mechanism It's Application and Comparison to Other Sensing Process

KEYWORDS: Distributed sensing,Brillouin,Raman,Rayleigh Scattering,Short Gauge sensing,Large Gauge sensing

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ABSTRACT — *This paper describes a distributed sensing process for measuring temperature ,strain ,pressure etc..different non linear scattering process like Brillouin,Raman,Rayleigh scattering process is explained.The distributed sensing process is explained by using the Brillouin Scattering process,it's applications are listed and a comparison of distributed sensing to that of short gauge sensing ,large gauge sensing is also listed.*

I. Introduction

In the process of physical sensing and data transmission the optical fiber cables are using very widely. The physical sensing process finds it's application mainly in structural health monitoring in order to determine temperature, strain, pressure etc..For the last four decades there have been tremendous development occurred in the area of application due to the independent nature towards the electromagnetic interference,small size and has a nature of operating in any type of environment. The use of Brillouin Scattering in optical fibers[1]results in the use of microwave signal processors, lasers, optical memories, phase conjugates, slow light generators and in distributed sensing[2].

II. Non-linear scattering in optical fibers

The scattering process is the result of inelastic scattering of a photon to a lower energy level[3]. The photons present in the medium will absorb this energy difference. The main non linear scattering process are stimulated Brillouin Scattering(SBS) and Stimulated Raman Scattering(SRS). The fundamental difference between these two non linear effects is that Stimulated Brillouin Scattering is a backward process where as SRS will occur in both forward and backward direction. The Brillouin Scattering is occurring as a result of the electrostriction process occurring with in the core of the optical fiber[3].It is preferred over the Raman scattering for distributed sensing process because simultaneous measurement of temperature and strain. Where as in Raman scattering strain is invariant.Table-1[8,9] gives a comparison between the non linear scattering process on the strain and temperature measurement.

TABLE-1.Comparison of non linear scattering process

Quantity(silica)	Brillouin	Raman
Gain bandwidth	~20-100MHz	~5THz
Peak gain coefficient	$5*10^{-11}$ m/W	$1*10^{-13}$ m/W
Frequency shift from Rayleigh at peak gain	11GHz	13THz
Free space wavelength shift	0.09nm	104nm
Spontaneous scattering	~20	~30

A .Principle

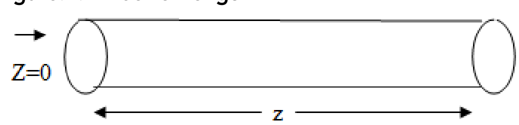
Brillouin scattering is well explained by using the process of Brillouin shift[4] .It is the process when light waves passes through the optical fiber there may be some kind of perturbation outside the fiber. This may lead to change of fiber property like refractive index profile,shape etc..This change causes a shift in the gain spectrum referred to as Brillouin shift, it is given by

$$V_B = \frac{2nVa}{\lambda} \qquad (1)$$

Where n is the refractive index of the fiber is the wavelength and v_a is the acoustic velocity. Here v_a is in direct relationship to V_B. The acoustic velocity depend mainly on the temperature and material density.So that if there is any change in quantities there will be a shift in the gain spectrum. The material using in optical fiber is silica which has the elastic property that will help in the strain measurement. The Brillouin distributed temperature and strain sensor is able to measure the stain and temperature up to 50Km[5].

Consider a fiber of length z[7],given in Fig.1 here the Brillouin scattering is well explained by using a set of equation which is considering under the steady state equation[1] are known as rate equation.

Figure.1.A fiber of length z



$$\frac{dIp}{dz} = -g_B I_s I_p - \alpha I_p \qquad (2)$$

$$\frac{dIs}{dz} = -g_B I_p I_s + \alpha I_s \qquad (3)$$

I_p , I_s represents pump and stroke intensities respectively, g_B is the Brillouin gain coefficient, α is the losses at pump or stroke frequency[4]. Taking the pump and stroke signals as a single vector I= .

III. Application

Distributed sensing system offer flexibility and speed of measurement in variety of operation. The distributed fibre optic sensor can be employed in various kinds of structural monitoring ,oil/gas monitoring, subsea flow, power line integrity etc..The important parameter[10] using for the sensing procedure is described below.

Stress sensing-This is using in the structural monitoring like structures and infrastructures. When considering about the safety of any structure the maximum amount of affordable stress is also taking into consideration.

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Strain sensing-The measure of displacement between two points in a structure is termed as strain sensing. In the case of an optical fibre the reference two points may change due to various environmental hazardous. In a strain sensor a fibre Bragg grating is sandwiched between layers of composite material.

Temperature sensing- The temperature from various systems like solar, nuclear reactor etc will affect optical fibre adversely. Different materials have different thermal expansion coefficient. According to the coefficient value temperature sensing will be achieved

IV. Comparison to various method

Fibre optic sensors found their application in distributed, short gauge and long gauge sensing.Distributed sensing finds it's application in large structures. Distributed sensing along with various scattering methods like Brillouin, Raman and Rayleigh. By using Brillouin scattering method it is possible to detect both the temperature and strain. Whereas Raman scattering is capable of measuring temperature and Rayleigh scattering is capable of temperature only.

The short gauge sensors are best suited for sensing in homogeneous materials such as steel. Here Fabry Perot Interferometer and Fibre Bragg Grating Spectrometry is using. These are able to measure strain and temperature.

Finally the long gauge sensors best suited for sensing in heterogeneous materials like concrete. Match Zehender Interferometry(MZI) and fibre bragg grating spectrometry is using. Here MZI is able to measure strain only where as FBG can measure both strain and temperature. The TABLE-2[11] given below summarizes the comparison.

TABLE-2.Distributed sensing.

Brillouin scattering	Strain and temperature
Raman scattering	Strain
Rayleigh scattering	Temperature

TABLE-3.Short gauge sensors.

Fibre bragg grating spectrometry	Strain and temperature
Match Zehender Interferometry	Strain

TABLE-4.Long gauge sensors.

Fibre bragg grating spectrometry	Strain and temperature
Match Zehender Interferometry	Strain

V. Conclusion

Distributed sensor using Brillioun scattering plays a key role in the fibre optic sensing. In this paper explained about the process of distributed sensing it's area of application. Mathematical expression for the non linear Brillouin scattering process is given. Different kinds of approaches for various applications are described. Finally a table level representation for various sensors is also mentioned.

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