도로포장의 평탄성 측정을 위한 광섬유 진동센서의 활용

Application of Fiber Optic Vibration Sensors for Roughness Inspection of Pavement Surface

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1. INTRODUCTION

For smart highway, continuous monitoring of pavement performance is very important. Main purpose of pavement of the highway is to provide the safe and efficient surface of the road to the vehicles.In order to achieve the safe and efficient surface of the usual highway, overall investigations after construction and every year inspection are performed. But smart highway needs continuous monitoring not just periodical inspection.

For maintenance of the pavement, inspections with 7.6 profilermeter or ARAN(Automatic Road Analyzer) are used, but they are not suitable for local in situ monitoring of the roughness of pavement while they are widely used for long range roughness of pavement. But the monitoring system of smart highway needs long term roughness measurement of pavement structure, we propose the vibration monitoring method using fiber optic sensors.

On the point of situation, which needs a technological system to estimate the status of the structure with higher accuracy and confidence, fiber optic sensor system, which is incorrosible semi-permanent, no influence by electromagnetic waves, and able to multiplex, will be expect to take an important part to assess the safety and residual estimate the life span of the highway pavement structure.

2. Characteristics of Fiber Optic Grating

Fiber Bragg grating(FBG) sensors, placing several fiber optic Bragg gratings as a certain length in one line of fiber, which use the change of the wavelength of light reflected from each gratings with temperature or strain change, has used more than 70% of fiber optic sensor applications.

On the core of the fiber instead of cladding, germanium is normally added to make the refractive index higher, however, a structural fault could occur on the process of the silica glass. In this case, when exposing strong ultraviolet ray on the core of the fiber optic, the bond-structure of germanium transforms and the refractive index changes. Fiber optic grating sensor use this symptom and repeatedly changing the refractive index of the core of fiber optic.

There are many ways to manufacture FBGs, however, using Excimer laser ultraviolet ray beam is the most popular way, such as <Figure 1>.

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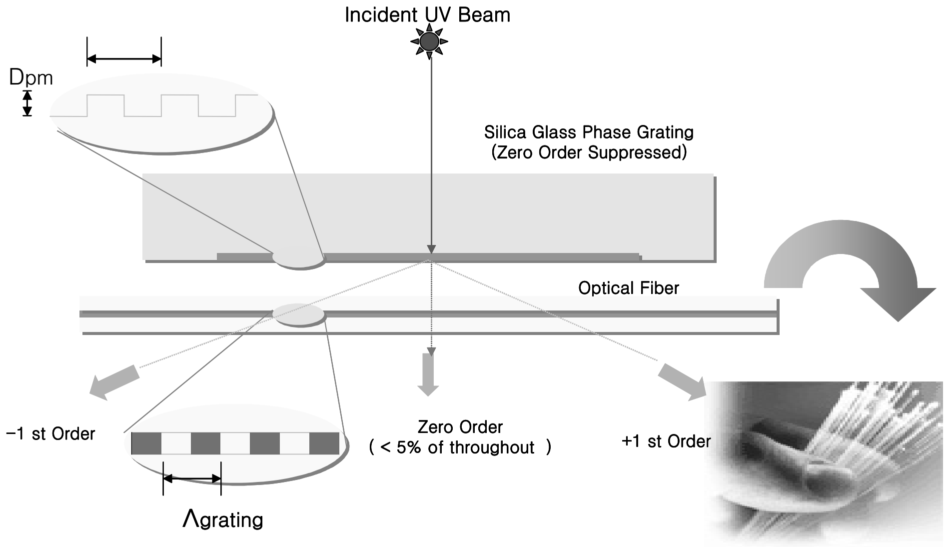

Figure 1. Manufacturing method of FBG sensor use ultraviolet-rays laser

Several gratings are used inside one line of fiber optic as atherefore, making each reflected wavelength changeof the gratings, it is easy to distinguish the physical properties that a specific grating has the specific reflected spectrum of light. We call this process as Wavelength Division Multiplication (WDM). With this process, the number of the grating which could be measured in one time is limited because of the limited line-width of the source of light. Generally, about 10 gratings are used in one fiber.

One of the biggest applications of Bragg grating sensor array, including the railway structure, is the smart structure, which could diagnose the status of the structure. Building railways, bridges, dams and other construction, fiber optic grating array can be embedded inside the concrete, and it is able to diagnose the safety of the structure by detecting strain of the interior of the structure. It is also being applied on diagnosing the wing of flying machines, such as air planes or helicopters.

As shown in <Figure 2>, reflecting Bragg wavelength is a function of effective refractive index and grating distance such as formula (1), and when the physical properties such as temperature or stress of the fiber optic grating sensor are permitted, the Bragg wavelength become different. Therefore, if you measure the change of the Bragg wavelength, it will be able to get the approval physical propertyon the fiber optic grating sensor.

First, the change($\triangle\lambda_B$) of Bragg center wavelength (λ_B) about strain (ϵ) change could be written as formula (1).

$$\triangle\lambda_B = \lambda_B\ (\ 1\ -\ P_e\ )\ \epsilon \qquad (1)$$

P_e is Photo-elastic Constant, and on the case of Germano- silicate glass, it has approximately the number of 0.22. $\epsilon$is the strain given on fiber optic grating.

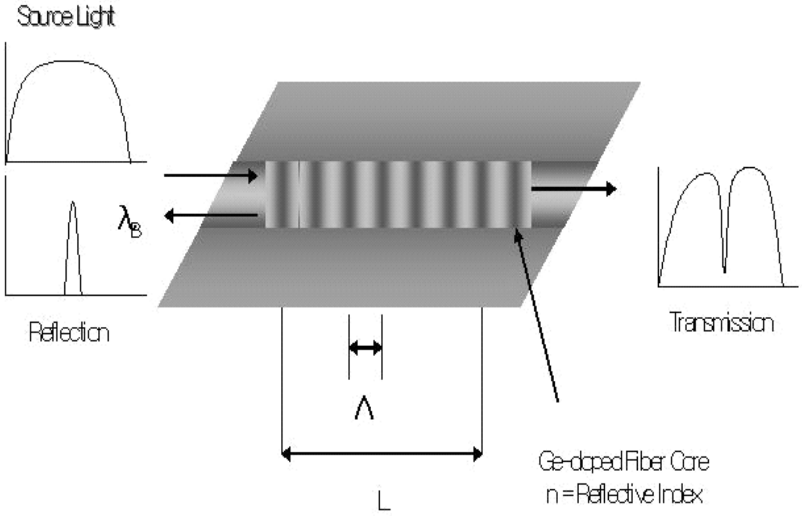

Figure 2. Structure of FBG sensor

3. Prototype of fiber optic vibration sensor package

In order to apply the vibration sensor to the highway, the package should be thin. Only the thin packagecan be embedded using saw cut strip line in the pavement. To minimize the damage which is generated by application of the sensor packages, we have to make the sensor thinner than saw cut width or we have to broaden the saw cut width more than the package thickness.

In this research, we tried to make the prototype as thin as possible. The fiber optic vibration sensor package prototype we made is shown in the Fig. 3. and the dimension of the prototype is 80mm x 50mm x 10mm.

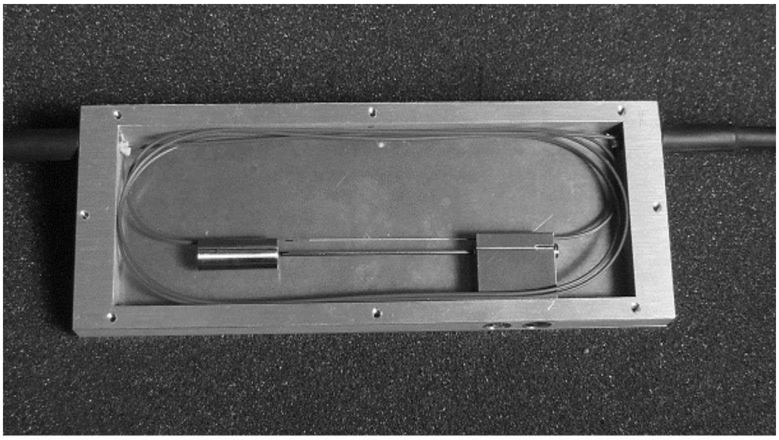

Figure 3. Inner structure of the proto type fiber optic vibration sensor

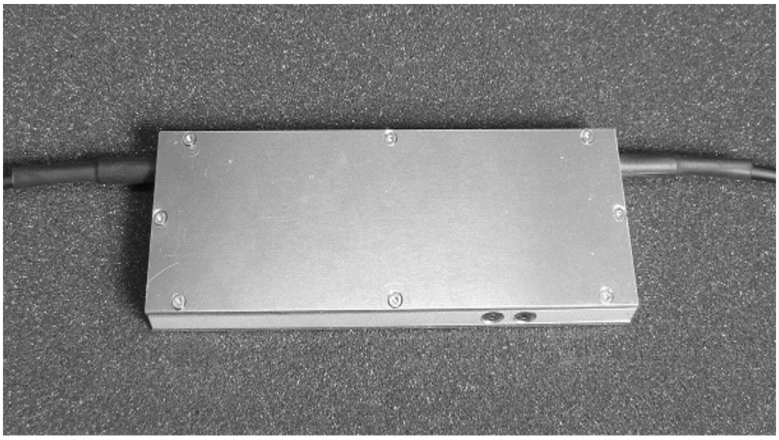

Figure 4. Outer shape of the proto type fiber optic vibration sensor

4. Laboratory impact test of the fiber optic prototype vibration sensor

For the test of the prototype, we made the impact application machine as shown in Fig. 5. The machine has a big swing which can impact the main body. The angle of the swing gives the energy to impact. The higher the angle of the swing is, the bigger the energy of the impact. The angle varies from 1 to 5°.

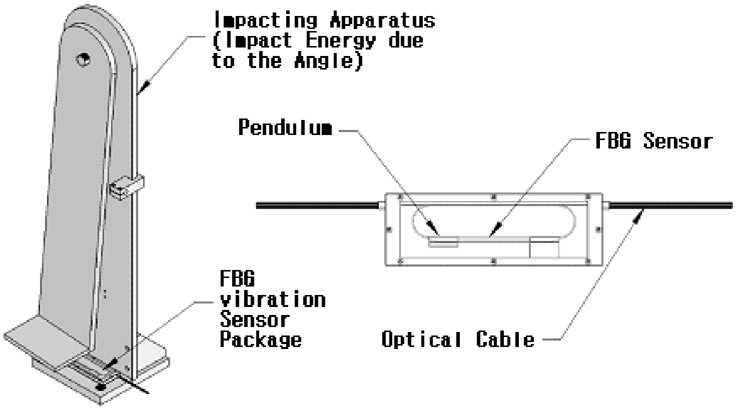

Figure 5. the pendulum type impact machine and fiber optic vibration sensor

The actual shapes of fiber optic vibration sensor and the pendulum type impact machine are shown in Fig. 6 and the laboratory experiment for impact is shown in Fig. 7.

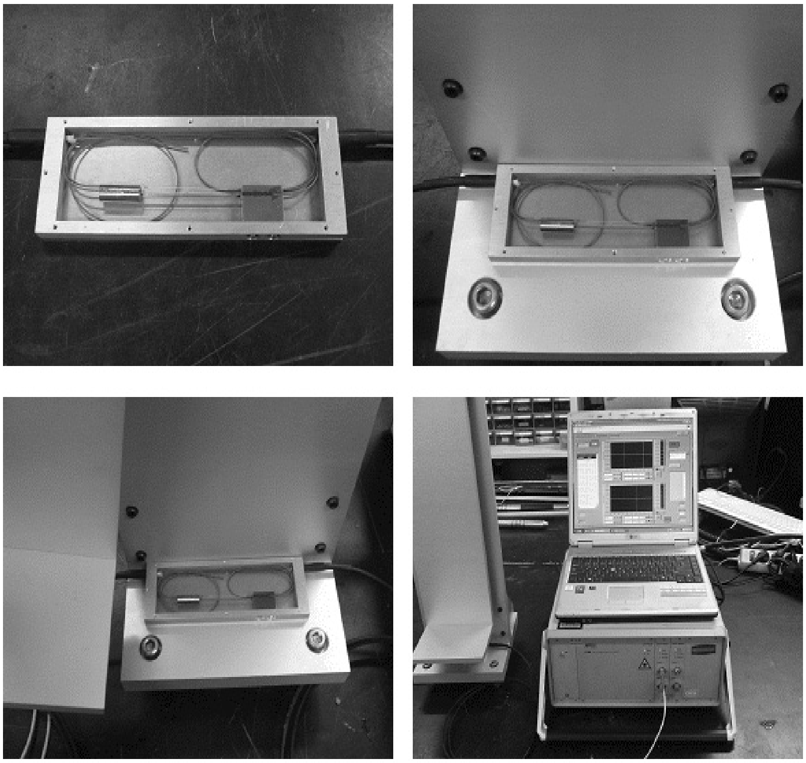

Figure 6. the pendulum type impact machine, fiber optic vibration sensor and the system

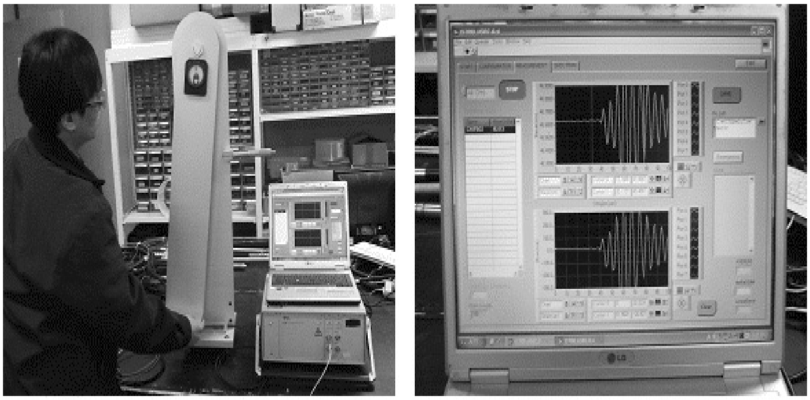

Figure 7. the impact test of the fiber optic vibration sensor and vibration shape in the screen

We had several experiments with the impact machine. The angle of the swing in the machine varied from 1 to 5°to test various impact energies. One of the real data from the impact test is shown in Fig. 8.

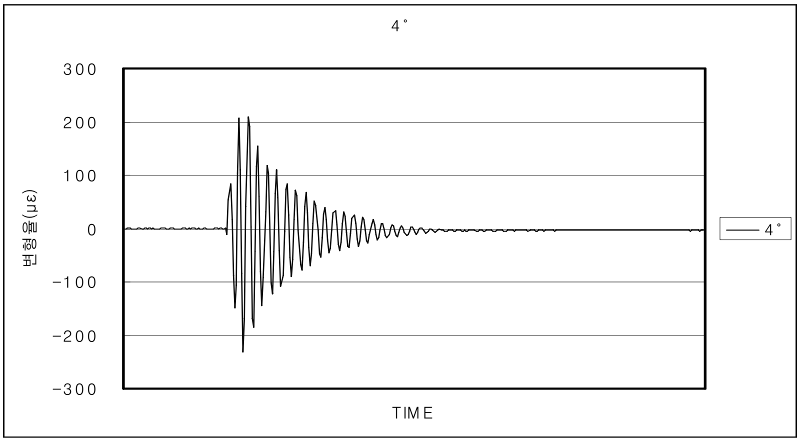

Figure 8. Vibration shape of the fiber optic vibration sensor by the impact test

As shown in Fig. 8, the data shows ordinary vibration by the impact and nice damping pattern.

5. Actual road test

After laboratory impact test, we tried actual road test with the prototype vibration sensor. We intended to monitor the ambient vibration by the vehicles, but the usual road showed just noises. We tried to find the road which has a step. After all, we found the road which has small step near Hongik University in Jochiwon and we install the vibration sensors to the curbs. The data showed the vibration due to vehiclevery clearly as shown in Fig. 9.

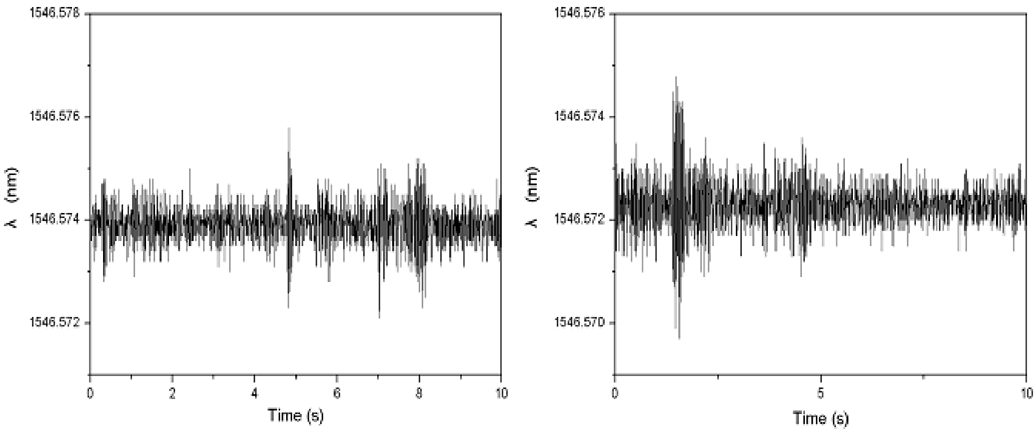

Figure 9. Vibration data from the fiber optic vibration sensor in the road test

6. Conclusions

We designed and produced prototype fiber optic vibration sensor packages. We had a laboratory impact testwith the sensors. The sensors showed very good responsibility to the impact and nice damping shape like other ordinary accelerometers. We also tried actual road test with the prototype vibration sensor. The ambient vibration by the vehicles was used for the experiment. We found the road which had a little steps near Hongik University in Jochiwon. We install the vibration sensors to the curbs. The data showed the good vibration patterns due to vehicles very clearly.

References

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